6.0 Risk Characterization

Risk characterization is the final step in the risk assessment process. It combines the information from the Exposure Assessment (Section 4) and Toxicity Assessment (Section 5) to estimate non-cancer hazards and cancer risks. In addition, risk characterization addresses the uncertainties underlying the risk assessment process (Section 10, Uncertainty Evaluation). This risk characterization was prepared in accordance with the EPA guidance on risk characterization (USEPA, 1992b; USEPA, 1995).

The methodology used to quantify potential non-cancer health effects and cancer risks is described in Section 6.1. The estimated non-cancer health hazards are discussed in detail in Section 6.2.1. and the estimated cancer risks in Section 6.2.2. Cancer and non-cancer results are summarized in Section 6.2.3. In Section 6.2.4 the differences in cancer risks and non-cancer hazards are compared between whole body and fillet fish samples collected from each site in the Columbia River Basin. Section 6.2.5 discusses the results of the multiple-species diet calculation, and; Section 6.2.6 shows how assumptions of percent inorganic arsenic impact the risk characterization.

Non-cancer health hazards and cancer risk estimates are calculated separately and reported separately. Because EPA uses different methods to evaluate these endpoints, non-cancer and cancer estimates cannot be combined.

6.1 Risk Characterization Methodology

6.1.1 Non-Cancer Health Effects

For non-cancer health effects, it is assumed that there is an exposure threshold below which adverse effects are unlikely to occur. In this assessment, the evaluation of non-cancer health effects involved a comparison of average daily exposure to chemicals in fish tissue with the EPA reference doses discussed in Section 5. The reference dose is an estimate of the daily exposure to a chemical that is unlikely to cause toxic effects. Potential health hazards from non-cancer effects for a specific chemical are expressed as a hazard quotient (HQ), which is the ratio of the calculated exposure (Section 4) to the reference dose for that chemical.

Both the estimated average daily doses from consuming fish and the reference doses are expressed in units of amount (in milligrams) of a chemical ingested per kilogram of body weight per day (mg/kg-day) (USEPA, 1989):

(Equation 6-1)

$$HQ = \frac{ADD}{RfD}$$

Where:

HQ = Chemical-specific hazard quotient (unitless)
ADD = Average daily dose (mg/kg-day)
RfD = Chemical-specific oral reference dose (mg/kg-day)

In this risk assessment, hazard quotients were first calculated for individual chemicals in each species at each study site and for the basin. These results are found in Appendices G1 and G2. However, because the fish collected for this study contain more than one contaminant, estimating non-cancer hazard by considering only one chemical at a time might significantly underestimate the non-cancer effects associated with simultaneous exposures to several chemicals. Therefore, to assess the overall potential for non-cancer hazards posed by multiple chemicals, the procedures recommended by EPA for dealing with mixtures were applied (USEPA, 1986a; USEPA, 1989).

EPA recommends that a total hazard index value first be calculated by summing all hazard quotients for individual chemicals regardless of the type of health effect that each chemical causes. This approach to assessing mixtures - adding the hazard quotients - is known as dose addition. Dose addition assumes that all compounds in a mixture have similar uptake, pharmacokinetics (absorption, distribution, and elimination in the body), and toxicological processes; and that dose-response curves of the components have similar shapes. Thus, calculating a total hazard index (adding all of the hazard quotients for all of the chemicals in a fish sample regardless of their health endpoint) has several uncertainties since it results in combining chemicals with reference doses that are based upon very different critical effects, levels of confidence, and uncertainty/modifying factors. Because the assumption of dose additivity is most properly applied to compounds that induce the same effect by the same mechanism of action, summing the hazard quotients for all chemicals to calculate a total hazard index could overestimate the potential for effects, and is therefore, only the first step in assessing non-cancer effects from a mixture.

If the total hazard index calculated is greater than one, EPA recommends that the hazard quotient values for chemicals with similar target organs or mechanisms of action (health endpoints) be summed to calculate a hazard index specific for each health endpoint (USEPA, 1986a). If an endpoint specific hazard index is greater than 1, unacceptable exposures may be occurring, and there may be concern for potential non-cancer effects. Generally, the greater the magnitude of the hazard index greater than 1, the greater the level of concern for non-cancer health effects.

For this risk assessment, both the total hazard index and endpoint specific hazard indices were calculated for each study site and for the basin. As previously discussed in Section 5, a total of seventeen non-cancer health endpoints were considered in developing endpoint specific hazard indices. Hazard indices are presented by species in Appendices O (resident fish species) and P (anadromous fish species). The non-cancer hazard discussion in this section (Section 6) further summarizes the information in these appendices, focusing on the range in total and endpoint specific hazard indices among the species and on the chemicals which contribute the most to non-cancer hazards.

6.1.2 Cancer Risk Assessment

The potential cancer risk from exposure to a carcinogen is estimated as the incremental increase in the probability of an individual developing cancer over a lifetime as a result of exposure to that carcinogen (USEPA, 1989). The term “incremental” means the risk due to environmental chemical exposure above the background cancer risk experienced by all individuals in a course of a lifetime. Approximately one out of every two American men and one out of every three American women will have some type of cancer during their lifetime (American Cancer Society, 2002). The risk characterization in this report estimates the cancer risk that may result from only one source - exposure to contaminants as a result of eating fish from the Columbia River Basin. Other cancer risks (i.e., "background" cancer risks) are not evaluated.

Under current risk assessment guidelines, EPA assumes that a threshold dose does not exist for carcinogens and that any dose can contribute to cancer risks (USEPA, 1986b). In other words, the risk of cancer is proportional to exposure and there is never a zero probability of cancer risk when exposure to a carcinogenic chemical occurs. Cancer risk probabilities were estimated by multiplying the estimated exposure level (average daily dose in mg/kg-day, discussed in Section 4) by the cancer slope factor (SF) for each chemical. The cancer slope factors used in this risk characterization were developed by EPA and are discussed in Section 5 and shown in Table 5-5. Cancer slope factors are expressed in units that are the reciprocal of those for exposure (i.e., $(mg/kg\text{-}day)^{-1}$). The cancer risk calculated for a chemical using this method represents the upper-bound incremental cancer risk that an individual has of developing cancer in their lifetime due to exposure to that chemical.

(Equation 6-2) $$Risk = ADD \times SF$$

Where:

Risk = Estimated chemical-specific individual excess lifetime cancer risk (probability; unit-less)
ADD = Chemical-specific average daily dose (mg/kg-day)
SF = Chemical-specific oral cancer slope factor $(kg\text{-}day/mg)^{-1}$

The excess cancer risk estimates in this report are shown in scientific notation format. These values should be interpreted as the upper-bound estimates of the increased risk of developing cancer over a lifetime. For example, 1×10^{-6} or 1E-06 (E=exponent of base 10) is the estimated upper-bound lifetime cancer risk of 1 in 1 million. Because these are upper-bound estimates, the true risks could be lower.

Because the fish collected for this study contain more than one carcinogen, estimating cancer risks by considering only one carcinogen at a time might significantly under-estimate the cancer risk associated with simultaneous exposures to several chemicals. Therefore, to assess the overall potential for cancer risks from exposure to multiple chemicals, the procedure recommended by EPA for dealing with mixtures were applied (USEPA, 1986a; USEPA, 1989).

EPA recommends that to assess the risk posed by simultaneous exposure to multiple carcinogenic chemicals, the excess cancer risk for all carcinogenic chemicals be summed to calculate a total cancer risk. This summing approach for carcinogens, also called response addition, assumes independence of action by the carcinogens in a mixture. The assumption in applying this method is that there are no synergistic or antagonistic interactions among the carcinogens in fish and that all chemicals produce the same effect, which in this case is cancer.

In interpreting cancer risks, different federal and state agencies often have different levels of concern for cancer risks based upon their laws and regulations. EPA has not defined a level of concern for cancer. However, regulatory actions are often taken when the risk of cancer exceeds a probability of 1 in 1,000,000 to 10,000 (i.e., 1×10^{-6} to $1 \times 10^{-4)}$. A level of concern for cancer risk has not been defined for this risk assessment.

For this risk assessment, the cancer risks for each chemical for a given species and study site were calculated (Appendix I). The cancer risks for each chemical were then summed to calculate the total cancer risks for each study site and for the basin. Appendices O (resident fish species) and P (anadromous fish species) show these total cancer risks by species as well as the contaminants with risks equal to or greater than $1 \text{ X } 10^{-5}$ for CRITFC's member tribal adults (average fish consumption, 70 years exposure duration). The cancer risk discussion in this section (Section 6) further summarizes the information in the Appendices focusing on the range in total cancer risk among the species and on the chemicals which contribute the most to cancer risks.

6.1.3 Chemicals Not Evaluated

As previously discussed in Section 1 of this report, a total of 132 chemicals were selected for analyses in all fish in this study. Forty (30%) of these chemicals, including 29 semivolatiles, 5 pesticides, 4 Aroclors, and 2 metals, were never detected in the tissue of any fish samples at the detection limits achieved for this study (Table1-4a-g). Twenty-three chemicals that were analyzed for did not have reference doses or cancer slope factors (see Section 5.0) so that cancer risks and non-cancer hazards using the methods described in Section 6.1.2 and 6.1.3 could not be estimated. A risk characterization was done for only the detected chemicals with toxicity values; a total of 82 chemicals.

6.1.4 Arsenic

As was previously discussed in Section 5.3.3, the non-cancer hazards and cancer risks discussed in Section 6.2.1 and 6.2.2, respectively, and the results presented in the appendices assume that for all fish species (resident fish and anadromous fish) caught in this study, 10% of the total arsenic is inorganic arsenic. Section 6.2.6 includes risk characterization results (using basin-wide data) assuming the alternative assumption that inorganic arsenic is only 1% of total arsenic for anadromous fish species.

6.1.5 Sample Type

In the CRITFC fish consumption study (CRITFC, 1994), respondents were asked to identify the fish parts they consume for each species. For most of the fish species sampled as a part of this study, the majority of the respondents said that they consume fish fillet with skin. However, a smaller proportion consumed other fish parts as well (head, eggs, bones and organs).

Information on the portions of fish that are consumed by the general public is not available. However, as previously discussed in the Exposure Section, respondents to the qualitative fish consumption survey conducted by EVS (EVS, 1998) for the Wheatland Ferry-Willamette Falls

Reach of the Willamette River, which is a part of the Columbia River Basin, indicated that all ethnic groups consume fillet tissue; however, other parts of the fish (eyes, eggs and skin) are also consumed as are whole body fish.

For this study, whole body samples as well as fillets were collected when possible, since the fish consumption surveys show that fillets as well as other body parts may be eaten. Both whole fish and fillet with skin samples were analyzed for all species except white sturgeon, bridgelip sucker, and eulachon. Sturgeon were analyzed as whole fish and fillet without skin (since it is unlikely that sturgeon skin is eaten). For bridgelip sucker and eulachon only whole body samples were collected.

Some of the risk characterization results summarized in Sections 6.2.1 and 6.2.2 are presented for fillet and whole body samples, and others only for fillet with skin samples (except for those species for which fillet with skin data were not available). However, non-cancer hazards and cancer risks were calculated for all samples collected and are included in the Appendices of this report. In addition, the impacts of sample type on the risk characterization results are discussed in more detail in Section 6.2.4, where the risk characterization results for whole body and fillet fish samples are compared using site specific data.

6.2 Risk Characterization Results

A summary and discussion of the non-cancer hazards (for adults and children for both the general public and CRITFC's member tribes) and excess cancer risks (for adults for the general public and CRITFC's member tribes) are presented in this section. More detailed information on the risk characterization results are presented in Appendices G through J and Appendices M through P for each fish species and tissue type analyzed in this study, for both individual study sites and for the Columbia River Basin:

- Appendix G1: Hazard quotients for individual chemicals for adults
- Appendix G2: Hazard quotients for individual chemicals for children
- Appendix H1: Percent contribution from individual chemicals to the total hazard index
- Appendix H2: Percent contribution from individual chemicals to endpoint-specific hazard indices
- Appendix I1: Estimated cancer risks for individual chemicals for adults, assuming 30 years exposure
- Appendix I2: Estimated cancer risks for individual chemicals for adults, assuming 70 years exposure
- Appendix J: Percent contribution of individual chemicals to total estimated cancer risk
- Appendix M: Comparison of the total and endpoint specific hazard indices across sites for a CRITFC tribal child (high fish consumption rate).
- Appendix N: Cancer risks across a range of consumption rates, by site and species
- Appendix O: Summary of risk characterization results (hazard indices and estimated cancer risks) for resident species
- Appendix P: Summary of risk characterization results (hazard indices and estimated cancer risks) for anadromous species

6.2.1 Non-Cancer Hazard Evaluation

6.2.1.1 Non-Cancer Hazard Evaluation for Resident Fish

Six species of resident fish were sampled in the Columbia River Basin: bridgelip sucker, largescale sucker, mountain whitefish, white sturgeon, walleye, and rainbow trout. Because of the large amounts of data that are presented in the appendices on the risk characterization for these species, one species (white sturgeon) was chosen as an example species to be discussed in detail. Data for the other resident fish species will be summarized. Tables 6-1 and 6-2 are identical to Tables 4.1 and 4.2, respectively, in Appendix O for sturgeon.

As previously discussed in Section 1, white sturgeon were collected from six study sites in the Columbia River Basin: 5 study sites in the main-stem Columbia River (study sites 6, 7, 8, 9L, and 9U) and in the Snake River (study site 13). Chemical analyses were performed on two tissue types, fillet without skin and whole body.

Table 6-1 summarizes both the total and end-point specific hazard indices calculated for white sturgeon. Results are presented for each of the six study sites that white sturgeon were caught as well as for the basin.

Table 6-1. Total hazard indices (HI) and endpoint specific hazard indices (at or greater than 1.0) for white sturgeon.

Consumption Rate/ Tissue Type		Health Endpoint	Hazard Index: Study site[e] CR -6	CR-7	CR-8	CR-9L	CR- 9U	SR- 13	Basin Average
General Public - Adult[a,b]									
AFC	FW	Immune system	–	–	–	–	2.1	–	0.6
		Total HI	0.8	0.6	0.6	1.2	2.9	0.9	0.9
AFC	WB	Immune system	na	na	1.1	–	–	na	0.9
		Total HI	na	na	1.5	1.0	1.2	na	1.3
HFC	FW	Liver	2.3	2.1	2.2	4.0	7.7	2.5	3.1
		Central nervous system	2.4	2.2	1.0	2.2	7.3	6.2	3.1
		Immune system	9.9	5.9	7.1	16	40	7.9	11
		Reproduction/development	2.4	2.2	1.0	2.2	7.3	6.2	3.1
		Total HI	15	11	11	23	55	17	18
HFC	WB	Liver	na	na	4.0	3.2	3.8	na	3.8
		Central nervous system	na	na	3.5	2.7	1.9	na	2.8
		Immune system	na	na	20	13	16	na	17
		Reproduction/development	na	na	3.5	2.6	1.9	na	2.7
		Total HI	na	na	29	20	23	na	24
General Public - Child[a,b]									
AFC	FW	Immune system	–	–	–	–	1.8	–	0.5
		Total HI	0.7	0.5	0.5	1.1	2.6	0.8	0.8
AFC	WB	**Total HI**	na	na	1.3	0.9	1.1	na	1.1
HFC	FW	Liver	2.9	2.6	2.8	5.1	9.8	3.2	4.0
		Central nervous system	3.1	2.9	1.3	2.8	9.4	7.9	4.0
		Immune system	13	7.6	9.1	21	51	10	14
		Reproduction/development	3.1	2.9	1.3	2.8	9.4	7.9	4.0
		Total HI	19	14	14	29	70	22	23
HFC	WB	Liver	na	na	5.1	4.1	4.9	na	4.9
		Central nervous system	na	na	4.5	3.4	2.4	na	3.9
		Immune system	na	na	26	16	21	na	22
		Reproduction/development	na	na	4.4	3.3	2.4	na	3.8
		Total HI	na	na	37	25	29	na	31
CRITFC's Member Tribes - Adult[c,d]									
AFC	FW	Liver	1.0	–	–	1.8	3.4	1.1	1.4
		Central nervous system	1.1	–	–	–	3.3	2.8	1.4
		Immune system	4.4	2.6	3.1	7.2	18	3.5	5.0
		Reproduction/development	1.1	–	–	–	3.3	2.8	1.4
		Total HI	6.6	4.7	4.7	10	24	7.5	7.9
AFC	WB	Liver	na	na	1.8	1.4	1.7	na	1.7
		Central nervous system	na	na	1.6	1.2	–	na	1.2
		Immune system	na	na	9.0	5.7	7.3	na	7.4
		Reproduction/development	na	na	1.5	1.2	–	na	1.2
		Total HI	na	na	13	8.8	10	na	11
HFC	FW	Liver	6.2	5.6	6.1	11	21	6.8	8.5
		Central nervous system	6.6	6.1	2.8	6.0	20	17	8.5
		Immune system	27	16	19	44	108	22	31
		Reproduction/development	6.6	6.1	2.8	6.0	20	17	8.5
		Selenosis	–	1.3	1.5	2.0	–	–	1.2
		Total HI	40	29	29	62	150	46	49
HFC	WB	Liver	na	na	11	8.8	10	na	10

Table 6-1. Total hazard indices (HI) and endpoint specific hazard indices (at or greater than 1.0) for white sturgeon.

Consumption Rate/ Tissue Type		Health Endpoint	Hazard Index						
			Study site [e]						Basin Average
			CR -6	CR-7	CR-8	CR-9L	CR- 9U	SR- 13	
		Central nervous system	na	na	9.6	7.2	5.1	na	7.6
		Immune system	na	na	56	35	45	na	45
		Reproduction/development	na	na	9.5	7.1	5.1	na	7.5
		Total HI	na	na	79	54	62	na	66
CRITFC's Member Tribes - Child[c,d]									
AFC	FW	Liver	1.8	1.7	1.8	3.2	6.2	2.0	2.5
		Central nervous system	2.0	1.8	–	1.8	6.0	5.1	2.5
		Immune system	8.0	4.8	5.8	13	32	6.4	9.2
		Reproduction/development	2.0	1.8	–	1.8	6.0	5.1	2.5
		Total HI	12	8.6	8.6	18	45	14	14
AFC	WB	Liver	na	na	3.2	2.6	3.1	na	3.1
		Central nervous system	na	na	2.9	2.2	1.5	na	2.5
		Immune system	na	na	17	10	13	na	14
		Reproduction/development	na	na	2.8	2.1	1.5	na	2.4
		Total HI	na	na	24	16	18	na	20
HFC	FW	Liver	12	11	12	21	41	13	16
		Cardiovascular	1.1	1.2	1.2	1.2			1.1
		Central nervous system	13	12	5.5	12	39	33	16
		Immune system	52	32	38	86	210	42	60
		Reproduction/development	13	12	5.5	12	39	33	16
		Hyperpigmentation/keratosis	1.1	1.2	1.2	1.2	–	–	1.1
		Selenosis	–	2.6	2.9	3.8	1.4	1.5	2.3
		Total HI	79	56	56	120	290	89	94
HFC	WB	Liver	na	na	21	17	20	na	20
		Cardiovascular	na	na	1.8	1.1	1.0	na	1.4
		Central nervous system	na	na	19	14	10	na	16
		Immune system	na	na	110	69	87	na	91
		Reproduction/development	na	na	18	14	9.9	na	16
		Hyperpigmentation/keratosis	na	na	1.8	1.1	1.0	na	1.4
		Selenosis	na	na	1.1	1.7	1.4	na	1.3
		Gastrointestinal	na	na	1.1	1.8	–	na	1.1
		Total HI	na	na	150	110	120	na	130

AFC = average fish consumption na =not applicable; sample type not analyzed at this study site
HFC = high fish consumption – = health endpoint <1.0 at that study site
Total HI = the sum of hazard quotients regardless of health endpoint FW - fillet without skin; WB - whole body

[a] AFC risk based on average U.S. per capita consumption rate of uncooked freshwater and estuarine fish for general public (adult) of 7.5 g/day, or 1 8-oz meal per month, and for general public (child) of 2.83 g/day, or 0.4 8-oz meal per month (USEPA, 2000b).

[b] HFC risk based on 99th percentile U.S. per capita consumption rate of uncooked freshwater and estuarine fish for general public of 142.4 g/day, or 19 8-oz meals per month, and for general public (child) of 77.95 g/day, or 11 8-oz meals per month (USEPA, 2000b).

[c] AFC risk based on average consumption rate for adult fish consumers in the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin of 63.2 g/day, or 9 8-oz meals per month, and for child fish consumers of 24.8 g/day, or 3 8-oz meals per month (CRITFC 1994).

[d] HFC risk based on 99th percentile consumption rate for adult fish consumers in the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin of 389 g/day, or 53 8-oz meals per month, and for child fish consumers of 162 g/day, or 22 8-oz meals per month (CRITFC 1994).

[e] Study sites are described in Table 1-1. CR = Columbia River ; SR = Snake River

For white sturgeon, the endpoints which had hazard indices greater than 1 for most of the populations were the immune system, liver, central nervous system, and reproduction/developmental, with the immune system endpoint having a higher hazard index than the other endpoints (Table 6-1). At the lowest (average) fish ingestion rates for the general public (average fish consumption, adults and children), only the immune endpoint exceeds a hazard index of 1 (high of 2.1). At the higher fish ingestion rates (e.g., the high ingestion rates for CRITFC's member tribal child), other endpoints with hazard indices greater than 1 begin to appear: liver, central nervous system, reproductive/developmental, cardiovascular, hyperpigmentation/keratosis, selenosis, and gastrointestinal.

Table 6-1 also shows that, as expected, the magnitude of both the end-point specific and total hazard indices increases proportionally to the estimated exposure for that population. For adults, the only differences in exposure for the four adult populations (general public, average and high fish consumption; CRITFC's member tribes, average and high fish consumption) are due to the different fish ingestion rates used. Thus, the hazard index increases proportionally to the fish ingestion rate. All other exposure parameters either remain constant for all four adult populations (fish contaminant levels, exposure frequency, body weight) or do not impact the exposure (exposure duration and averaging time) for the reasons discussed in Section 4.9 (Averaging Time). This direct relationship between the hazard index and the fish ingestion rates for adults is shown in Figure 6-1 and Table 6-2.

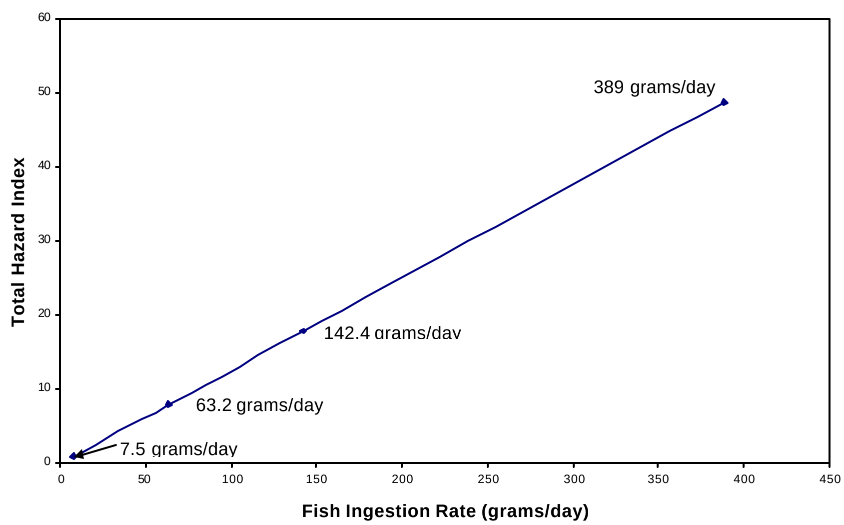


Figure 6-1. Total hazard index versus fish consumption rate for adults. White sturgeon, Columbia River Basin-wide average concentrations (fillet without skin).

Table 6-2. Comparison of Estimated Total Hazard Indices Among Adult Populations. White sturgeon (whole body) from Columbia River, study site 8			
Population	**Ingestion rate (g/day)**	**Total hazard index**	**Approximate ratio of hazard index to that of general public adult with average fish consumption**
General public			
average fish consumption	7.5	1.5	1
high fish consumption	142.4	29	19
CRITFC's member tribal			
average fish consumption	63.2	13	9
high fish consumption	389	79	50

Table 6-2 shows the total hazard indices estimated for adults consuming sturgeon at Columbia River study site 8 (whole body samples) at each ingestion rate. Also shown is the ratio of the total hazard indices for CRITFC's member tribes (average and high fish consumption) and the general public (high fish consumption) to that for the general public, average fish consumption. The ingestion rate and exposure for adults is lowest at the average fish consumption rate for the general public and increases proportionally for the other populations as their ingestion rates increase. For example, the ingestion rate for the high fish consumers, general public, is about 19 times higher than that for the average fish consumer. Thus, the exposure estimated and the total hazard indices calculated for the general public, high fish consumer would be expected to be 19 times higher that those calculated for the general public, average fish consumer. This relationship also holds true for the endpoint specific hazard indices calculated for each study site and the basin. The hazard index for the immune system (Table 6-1) was about 1 at Columbia River study site 8 for the general public, average fish consumption (whole body fish) and 20 for the high fish consumption, general public - approximately a 20 fold difference (not exactly 19 fold as shown in the Table 6-2 due to rounding of hazard indices).

A similar comparison can be made for the populations of children assessed in this risk assessment. However, as discussed in Section 4.3, for children, exposures vary by ingestion rate as well as by body weight and exposure duration. This is because of the difference in the ages of the children in the two different fish consumption studies used to estimate fish ingestion rates for children (general public children versus CRITFC's member tribal children). Table 6-3 shows the ratio of hazard indices for three of the child populations (general public, high fish consumption; CRITFC's member tribes, average and high fish consumption) compared to that of the general public child with average fish consumption using data for the Columbia River (study site 8), whole body sturgeon. As can be seen from this table, the hazard indices estimated for CRITFC's member tribal children at the high ingestion rate were over 100 times those estimated for general public children at the average ingestion rate.

Table 6-3. Comparison of Estimated Total Hazard Indices Among Child Populations White sturgeon (whole body) from Columbia River, study site 8

Population	Ingestion rate (g/day)	Total hazard index	Ratio of hazard index to that of general public with average fish consumption
General public			
average fish consumption	2.83	1.3	1
high fish consumption	77.95	37	28
CRITFC's member tribal			
average fish consumption	24.8	24	18
high fish consumption	162	150	115

A review of Table 6-1 also shows that for the general public at the average ingestion rate, the hazard indices for children were about 0.9 of those for adults; the hazard indices for general public children at the high ingestion rate were about 1.3 times those for general public adults, high ingestion rate. For example, the basin-wide total hazard index was 23 at the high fish consumption rate (77.95 grams/day) assumed for the general public child compared to 18 for the high fish consumption rate (142.2 grams/day) assumed for the general public adult. For CRITFC's member tribes, the hazard indices for children at the average and high fish ingestion rates were both about 2 times those for CRITFC's member tribal adults at the average and high ingestion rates, respectively.

The differences in hazard indices between adults and children as well as the differences among sites and at different fish ingestion rates is shown in Figures 6-2a-d. These figures show a comparison of the total hazard indices for sturgeon (fillet without skin) across sites for both adults and children at different fish ingestion rates (note that the scale of the Y axis increases from Figure 6-2a through Figure 6-2d). Figure 6-2a compares the total hazard indices for general public adults and children at the average fish ingestion rate. The hazard index varies by site with the Hanford Reach of the Columbia River (study site 9U) having the highest values (hazard indices of 2.9 for adults and 2.6 for children). At a given site, the total hazard index for a child is about 0.9 that of that for an adult at the average fish ingestion rate for the general public. Figure 6-2d compares the results for CRITFC tribal adults and children at the high ingestion rate. Again, the total hazard index varies across sites with the Hanford Reach of the Columbia River (study site 9U) having the highest values (hazard indices of 150 for adults and 290 for children). At a given site, the total hazard index for a child is about 2 times that for those of adults at the high fish ingestion rate for CRITFC tribal adults and children.

The chemicals which had hazard quotients at or greater than 1.0 (i.e., exposures for that chemical were greater than the reference dose) for sturgeon for most populations were total Aroclors, total DDT, and mercury (Table 6-4, same as Table O-4.2 in Appendix O). Selenium, arsenic, and chromium were generally greater than 1.0 only at the highest exposures (high fish consumption rates for CRITFC's member tribal adults and children). It is useful to compare the chemicals contributing the most to non-cancer hazard for sturgeon (Table 6-4) with the hazard indices for each endpoint (Table 6-1). Aroclors, which had the highest hazard quotients (Table 6-4) were also the only chemicals contributing to the endpoint of immunotoxicity. Thus the endpoint specific hazard indices for immunotoxicity were also the highest of all hazard indices (Table 6-1).

Mercury was the major contributor to the endpoints of central nervous system and reproduction/developmental, and DDT to the liver endpoint. Thus the hazard quotients calculated for Aroclors, mercury, and DDT (Table 6-4) were the major contributors to (and often equal or close to) the hazard indices for the endpoints of immunotoxicity, central nervous system and reproduction/development, and liver, respectively (Table 6-1). The hazard indices greater than 1.0 for the cardiovascular and hyperpigmentation endpoints (Table 6-1) were primarily a result of exposures greater than the reference dose for arsenic. Selenosis was a result of exposures greater than the reference dose for selenium, and gastrointestinal effects were a result of exposures greater than the reference dose for chromium.

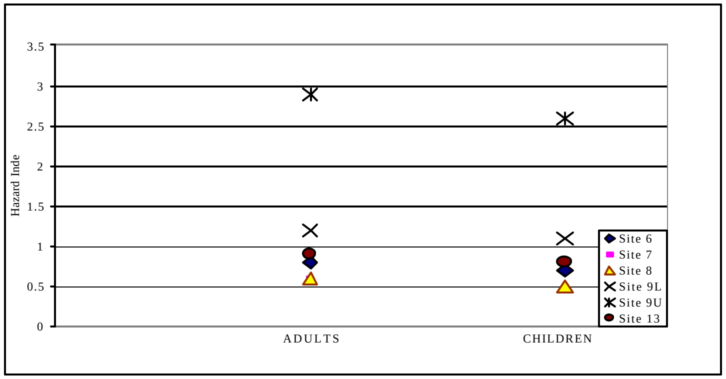


Figure 6-2a. Hazard indices for general public adults and children, average fish consumption rate of white sturgeon fillets. Note that hazard indices are the same at study site 7 and 13.

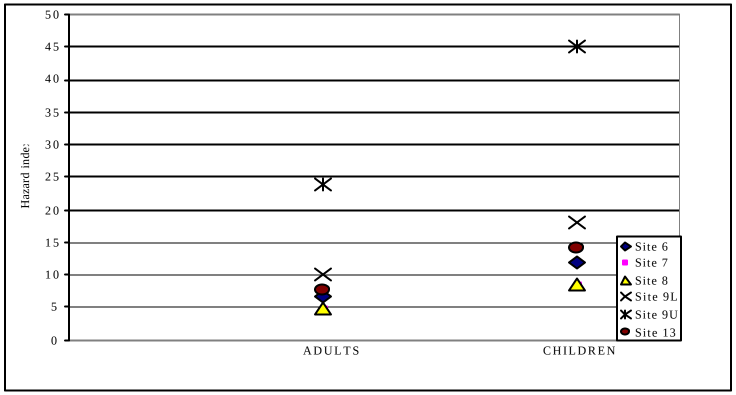


Figure 6-2b. Hazard indices for CRITFC's member tribal adults and children, average fish consumption rate for white sturgeon fillets. Note that hazard indices are the same at study site s 7 and 13.

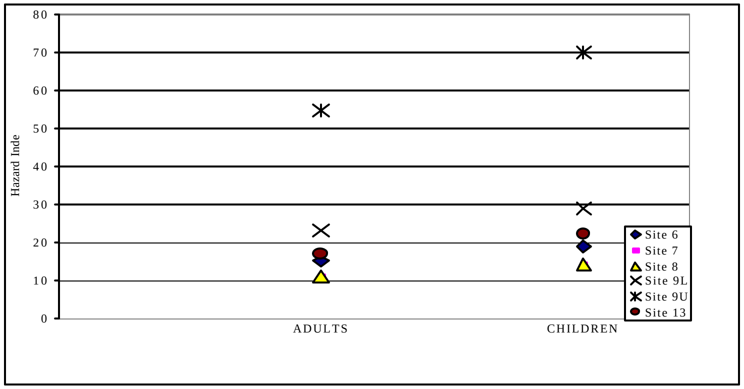


Figure 6-2c. Hazard indices for general public adults and children, high fish consumption rate of white sturgeon fillets. Note that hazard indices are the same for study sites 7 and 13.

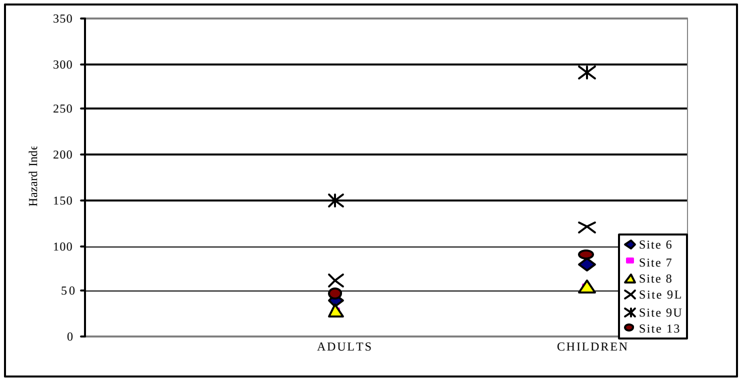


Figure 6-2d. Hazard indices for CRITFC's member tribal adults and children, high fish consumption rate of white sturgeon fillets. Note that hazard indices are the same at study sites 7 ad 13.

It is important to point out that there are no reference doses available for dioxins, furans and dioxin-like PCB congeners. Therefore, hazard quotients could not be calculated for these classes of chemicals and their potential impact on the magnitude of non-cancer hazards (i.e., endpoint specific hazard indices and total hazard indices) could not be evaluated.

Table 6-4. Chemicals having hazard quotients at or greater than 1.0 in white sturgeon.

	Adults			Children			
Tissue Type	**Hazard Quotient**		**Study sites[a] with Values >1**	**Chemical**	**Hazard Quotient**		**Study Sites[a] with Values >1**
	AFC	**HFC**			**AFC**	**HFC**	
General Public							
Fillet without skin							
Total Aroclors	2.1	5.9-40	6[b],7[b],8[b],9L[b],9U,13[b]	Total Aroclors	1.8	7.6-51	6[b],7[b],8[b],9L[b],9U,13[b]
Total DDT	–	1.5-7.1	6,7,8,9L,9U,13	Total DDT	–	1.9-9.1	6,7,8,9L,9U,13
Mercury	–	1.0-7.3	6,7,8,9L,9U,13	Mercury	–	1.3-9.4	6,7,8,9L,9U,13
Whole body							
Total Aroclors	1.1	13-20	8,9L[b],9U[b]	Total Aroclors	–	17-26	8,9L,9U
Total DDT	–	2.6-3.7	8,9L,9U	Total DDT	–	3.4-4.7	8,9L,9U
Mercury	–	1.9-3.5	8,9L,9U	Mercury	–	2.4-4.4	8,9L,9U
CRITFC's Tribal Members							
Fillet without skin							
Total Aroclors	2.6-18	16-110	6[b],7[b],8[b],9L,9U,13[b]	Total Aroclors	4.8-32	32-210	6,7,8,9L,9U,13
Total DDT	1.3-3.2	4.1-20	6,7,8,9L,9U	Total DDT	1.2-5.8	8.0-38	6,7,8,9L,9U,13
Mercury	1.0-3.3	2.8-20	6,7,8[b],9L[b],9U,13	Arsenic	–	1.1-1.2	6,7,8,9L
Selenium	–	1.3-2.0	7,8,9L	Mercury	1.8-6.0	5.5-39	6,7,8[b],9L,9U,13
				Selenium	–	1.4-3.8	7,8,9L,9U,13
Whole body							
Total Aroclors	5.7-9.0	35-56	8,9L,9U	Total Aroclors	11-17	69-110	8,9L,9U
Total DDT	1.2-1.6	7.8-10	8,9L,9U	Total DDT	2.1-3.0	14-20	8,9L,9U
Mercury	1.2-1.5	5.1-9.5	8,9L,9U[b]	Arsenic	–	1.0-1.8	8,9L,9U
				Chromium	–	1.1-1.8	8,9L
				Mercury	1.5-2.8	9.9-19	8,9L,9U
				Selenium	–	1.1-1.7	8,9L,9U

AFC = average fish consumption; HFC = high fish consumption;
- = <1; [A]study sites are described in Table 1-1. [B]HFC only

The summary of the results of the non-cancer hazard evaluation for the other resident fish species are shown in Appendix O by species. Summaries of the endpoint specific and total hazard indices and of the chemicals having hazard quotients at or greater than 1 are shown in Tables 1.1 and 1.2 (bridgelip sucker), 2.1 and 2.2 (largescale sucker), 3.1 and 3.2 (mountain whitefish), 4.1 and 4.2 (white sturgeon), 5.1 and 5.2 (walleye), and 6.1 and 6.2 (rainbow trout). A review of these tables shows that:

- The total hazard indices and endpoint specific hazard indices increase among the general public and CRITFC's member tribal populations as the exposures for that population increase;

- The endpoints which are more frequently greater than a hazard index of 1 are immune system (due to Aroclors), liver (due primarily to DDE for most species), and central nervous system and reproduction/developmental (due primarily to methyl mercury), with the immune system endpoint usually having a higher hazard index than the other endpoints. These hazard indices vary among sites for a given species and among species;

- At the lowest (average) fish ingestion rates for the general public (adults and children), the endpoint-specific hazard indices were at or less than 1 for all of the resident fish with the exception of sturgeon and whitefish at the Hanford Reach of the Columbia River (9U) where hazard indices for immunotoxicity were greater than 1 (high of 3 for whitefish).

- For the more highly exposed populations (e.g., at the high fish ingestion rates for CRITFC's member tribes), endpoint specific hazard indices for reproduction/development and central nervous system, immunotoxicity, and liver are greater than 1 at most sites for most species. For mountain whitefish and white sturgeon, hazard indices for the most contaminated study site (Columbia River, study site 9U) were greater than 100 for the immunotoxicity endpoint.

- At these highest ingestion rates for CRITFC's member tribal adults and children, other endpoints with hazard indices greater than 1 begin to appear for some species. These endpoints include cardiovascular and hyperpigmentation/keratosis, selenosis, gastrointestinal, kidney, and metabolism. These effects were primarily the result of exposures greater than the reference dose for arsenic; selenium; chromium; cadmium; and nickel and zinc, respectively. For walleye, thallium also contributes to the overall hazard index calculated for liver. The highest endpoint-specific hazard index for these endpoints was approximately 4.0.

Table 6-5 is a summary of the ranges in endpoint specific hazard indices across study sites for each resident fish species. Results are shown for both average and high fish consumption rates for the general public and CRITFC tribal member adults. Hazard indices are shown only for those endpoints that most frequently exceed a hazard index of 1 (reproduction/development and the central nervous system, immunotoxicity, and liver). It should be kept in mind that not all fish species were caught at the same sites and that sample numbers varied by species.

Table 6-5 Summary of ranges in endpoint specific hazard indices across study sites for adults who consume resident fish from the Columbia River Basin.

Species	N	Non-cancer endpoints which most frequently exceed a hazard index of 1 for all species		
		Reproductive/ Developmental And Central Nervous System	Immunotoxicty	Liver
General Public - Adult				
Average Fish Consumption				
bridgelip sucker	*3*	<1	<1	<1
largescale sucker	*19*	<1	<1	<1
mountain whitefish	*12*	<1	<1 to 3	<1
white sturgeon	*16*	<1	<1 to 2	<1
walleye	*3*	<1	<1	<1
rainbow trout	*7*	<1	<1	<1
High Fish Consumption				
bridgelip sucker	*3*	<1	6	2
largescale sucker	*19*	2 to 7	1 to 8	<1 to 3
mountain whitefish	*12*	<1 to 3	1 to 50	<1 to 4
white sturgeon	*16*	1 to 7	6 to 40	2 to 8
walleye	*3*	4	1	1
rainbow trout	*7*	1 to 2	1 to 2	<1
CRITFC's Member Tribal Adult				
Average Fish Consumption				
bridgelip sucker	*3*	<1	3	1
largescale sucker	*19*	<1 to 3	<1 to 3	<1 to 1
mountain whitefish	*12*	<1 to 1	<1 to 22	<1 to2
white sturgeon	*16*	<1 to 3	3 to 18	<1 to 3
walleye	*3*	2	<1	<1
rainbow trout	*7*	<1	<1	<1
High Fish Consumption				
bridgelip sucker	*3*	2	17	6
largescale sucker	*19*	5 to 20	<1 to 21	<1 to 7
mountain whitefish	*12*	<1 to 7	4 to 140	<1 to 11
white sturgeon	*16*	3 to 20	16 to 108	6 to 21
walleye	*3*	10	4	4
rainbow trout	*7*	4 to 5	3 to 4	<1

N = number of samples; all samples are fillet with skin except white sturgeon which is fillet without skin.
Bridgelip sucker and eulachon are whole body samples.

Figure 6-3 summarizes the total basin-wide hazard indices for resident fish species using average and high fish consumption rates for the general public and CRITFC's member tribal adult populations. This figure shows that mountain whitefish and white sturgeon had the highest total basin-wide hazard indices, followed by sucker, walleye, and rainbow trout. It also shows that for all species, the total hazard indices are highest for CRITFC's member tribal adults at the high fish ingestion rates (389 g/day) followed by the general public adult, high ingestion rate (142.4 g/day); CRITFC's member tribal adults, average ingestion rate (63.2 g/day); and general public adult, average ingestion rate (7.5 g/day).

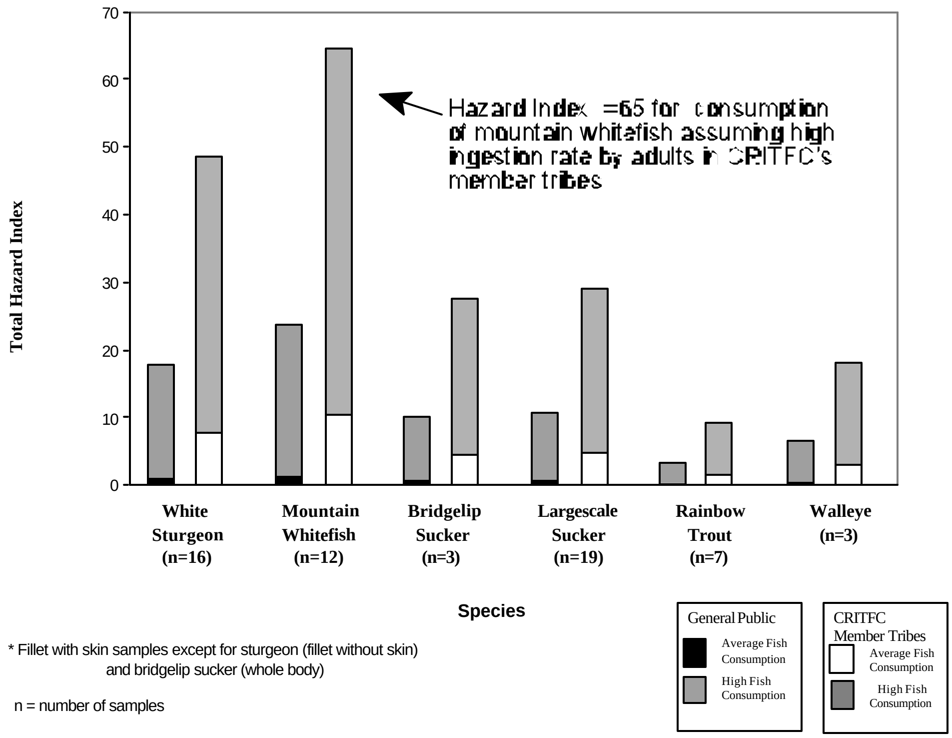


Figure 6-3. Adult total non-cancer hazard indices for resident fish species* using basin-wide average data.

For a more detailed comparison of the total and endpoint specific hazard indices, see Appendix M, where hazard indices are compared for all resident species across study sites for CRITFC's member tribal children with a high fish consumption rate (162 g/day or 5 meals per week).

The contribution from specific chemicals and classes of chemicals to the overall non-cancer hazard for resident fish species is shown in Table 6-6. These results were calculated using Columbia River Basin average concentrations for fillet without skin samples, except for those species where such sample types were not available (bridgelip sucker, whole body; white sturgeon, fillet without skin). The number of samples used to compute the basin-wide averages vary among species, and for some species represent only a few samples (e.g., 3 samples for walleye and bridgelip sucker). The results in Table 6-6, which are also depicted in the charts in Figures 6-4 through 6-9, show that the percent contribution of specific chemicals to the total hazard index differs among the resident fish species. For example, Aroclors contribute 83% to the total non-cancer hazard for mountain whitefish, but only 20% for walleye. Total DDT contribution to the total hazard index ranges from 3-21% among the species and methyl mercury from about 6-54%. Except for thallium for walleye (percent contribution of 14%), the only chemicals contributing greater than 5% to the non-cancer hazards for resident fish species are Aroclors, total DDT, and mercury.

Table 6-6. Percent contribution of contaminant groups to total non-cancer hazards for resident fish species. Based on Columbia River Basin-wide averages.

	white sturgeon	bridgelip sucker	largescale sucker	mountain whitefish	walleye	rainbow trout
Tissue Type	*FW*	*WB*	*FS*	*FS*	*FS*	*FS*
Number of samples	*16*	*3*	*19*	*12*	*3*	*7*
Total metals	**22**	**18**	**50**	**9**	**77**	**55**
Mercury	17	6	45	7	54	46
Arsenic	1	2	<1	<1	4	ND
Chromium	<1	1	1	<1	1	1
Manganese	<1	3	<1	<1	<1	<1
Selenium	2	1	1	1	2	3
Thallium	ND	ND	ND	ND	14	ND
Zinc	<1	1	1	<1	1	2
Other Metals	<1	4	1	<1	1	2
Total Aroclors	**63**	**60**	**40**	**83**	**20**	**42**
Total Pesticides	**15**	**21**	**10**	**8**	**3**	**3**
Total DDT	13	21	9	7	3	3
Other Pesticides	2	<1	<1	1	ND	ND

FW = fillet without skin; FS = fillet with skin; WB = whole body; ND = Not Detected

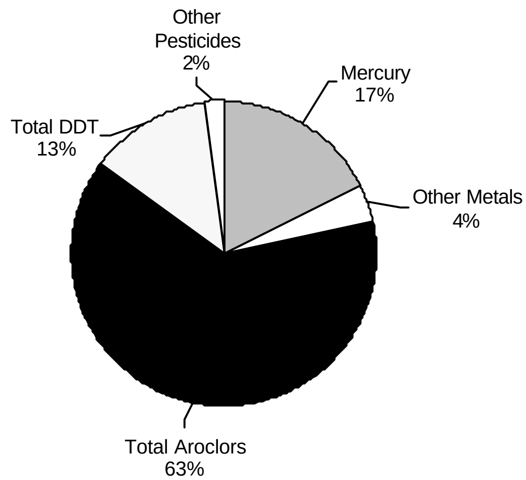


Figure 6-4. Percent contribution of basin-wide average chemical concentrations to non-cancer hazards from consumption of white sturgeon fillet without skin. Number of samples = 16.

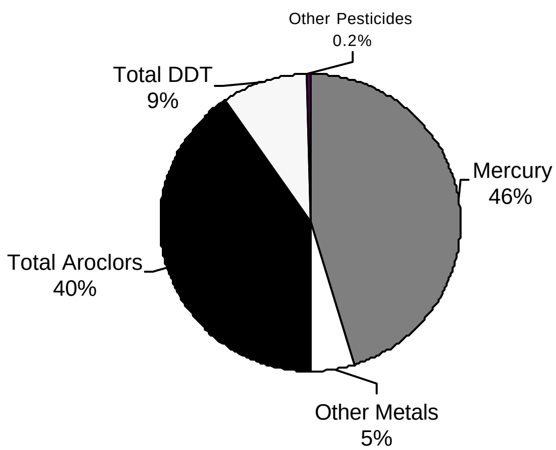


Figure 6-5. Percent contribution of basin-wide average chemical concentrations of non-cancer hazards from consumption of largescale sucker fillets with skin. Number of samples = 19.

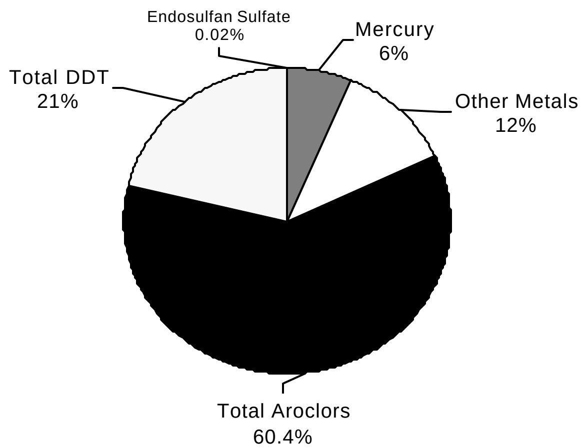


Figure 6-6. Percent contribution of basin-wide average chemical concentrations to non-cancer hazards from consumption of whole body bridgelip sucker. Number of samples = 3.

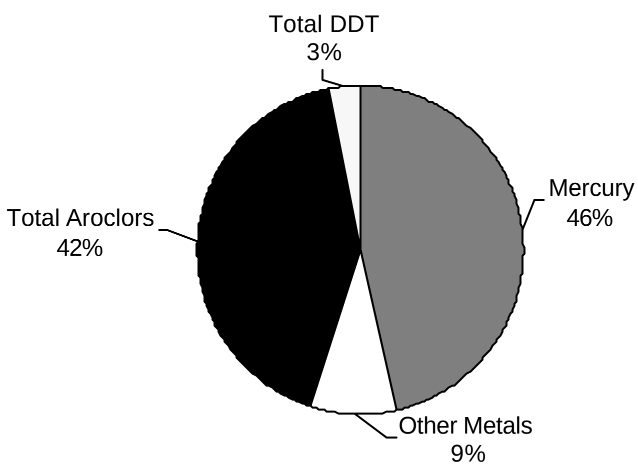


Figure 6-7. Percent contribution of basin-wide average chemical concentrations to non-cancer hazards from consumption of rainbow trout fillet with skin. Number of samples = 7.

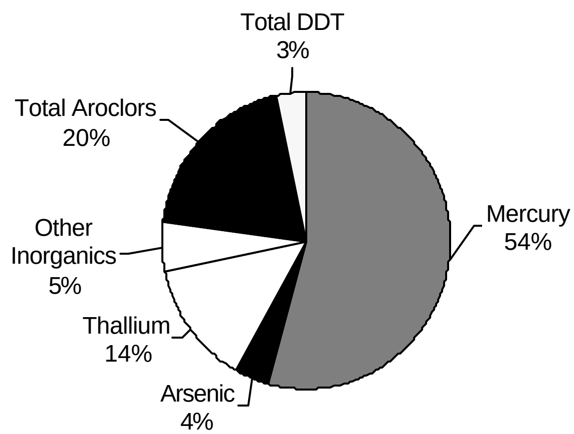


Figure 6-8. Percent contribution of basin-wide average chemical concentrations to non-cancer hazards from consumption of walleye fillet with skin. Number of samples = 3.

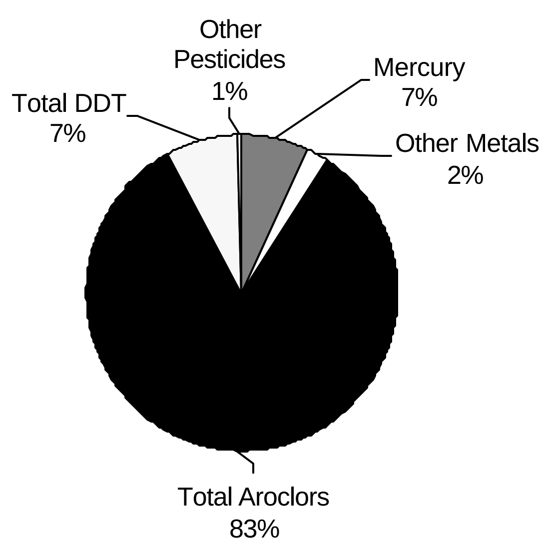


Figure 6-9. Percent contribution of basin-wide chemical concentrations to non-cancer hazards from consumption of mountain whitefish fillet with skin. Number of samples = 12.

6.2.1.2 Non-cancer Hazard Evaluation for Anadromous Fish

The anadromous fish sampled in the Columbia River Basin were coho salmon, fall chinook salmon, spring chinook salmon, steelhead, eulachon, and Pacific lamprey. The summary of the results of the non-cancer hazard evaluation for these anadromous fish species are shown in Appendix P by species. Summaries of the endpoint-specific and total hazard indices and of the chemicals having hazard quotients greater than 1 are shown in Tables 1.1 and 1.2 (coho salmon), 2.1 and 2.2 (fall chinook salmon), 3.1 and 3.2 (spring chinook salmon), 4.1 and 4.2 (steelhead), -5.1 and 5.2 (eulachon), and 6.1 and 6.2 (Pacific lamprey). As with the resident fish species, the values of the total hazard indices and endpoint-specific hazard indices increase among all of the populations as the exposure to that population increases.

Because the results for coho salmon, fall chinook, spring chinook, and steelhead were similar, they are summarized as a group. The results for eulachon and lamprey are discussed separately.

Tables 1.1 and 1.2 (coho salmon), 2.1 and 2.2 (fall chinook salmon), 3.1 and 3.2 (spring chinook salmon), and 4.1 and 4.2 (steelhead) show that:

- At the average fish ingestion rates for the general public, adults and children, the endpoint specific hazard indices were less than 1.0.

- The endpoints which had hazard indices greater than 1 most frequently for salmon and steelhead were immunotoxicity (due to Aroclors) and reproductive/developmental and central nervous system (due primarily to mercury). In general, the hazard indices for the immunotoxicity endpoint for salmon and steelhead were much lower and did not vary as much across study sites as those for the resident fish species with the highest contaminant levels (largescale sucker, mountain whitefish, and white sturgeon).

- As exposures increase, other endpoints with hazard indices greater than 1 begin to appear. These include: cardiovascular and hyperpigmentation/keratosis; metabolism; selenosis; gastrointestinal; and kidney, resulting primarily from exposures greater than the reference dose to arsenic; nickel and zinc; selenium; chromium; and cadmium, respectively. The highest hazard indices for these endpoints at the highest ingestion rates were at or less than 4. At these exposures, hazard indices for immunotoxicity, reproduction/development, and central nervous system are greater than 1 for most sites.

Pacific lamprey were collected at 2 study sites, Willamette Falls (study site 21) and Fifteen Mile Creek (study site 24). Pacific lamprey results were similar to those for salmon and steelhead in that, at the average fish ingestion rates for the general public, adults and children, the endpoint specific hazard indices never exceed 1.0. In examining endpoint specific hazard indices with increasing exposure, the immune system hazard index is exceeded first. The estimated endpoint specific hazard index for immunotoxicity, which is the largest contributor to the total hazard index for Pacific lamprey is due to exposures greater than the reference dose for Aroclors. At the same ingestion rates, the endpoint specific hazard indices for immunotoxicity were higher for lamprey than for salmon and steelhead.

Eulachon (smelt) were caught at only one study site, Columbia River study site 3, and analyzed as whole body samples. Two endpoint specific hazard indices were exceeded (cardiovascular and hyperpigmentation/keratosis) at the high fish consumption rates for CRITFC's member tribal adults (hazard index of 1.7) and children (hazard index of 3.2) (see Table 5.1). These exceedances were a result of arsenic exposures greater than the reference dose (Table 5.2).

Table 6-7 is a summary of the ranges in endpoint specific hazard indices across study sites for anadromous fish. Results are shown for both average and high fish consumption rates for the general public and CRITFC tribal member adults. Hazard indices are shown only for the three endpoints which frequently exceeded a hazard index of 1: reproduction/development and the central nervous system, immunotoxicity, and liver. It should be kept in mind that not all species were caught at the same study sites and that sample numbers varied by species.

Figure 6-10 shows the relative differences in total hazard indices in the Columbia River Basin for anadromous fish species using average and high fish consumption rates for general public adults and for CRITFC's member tribal adults. The total hazard index is highest for lamprey, followed by salmon and steelhead, which are in the same range, and then eulachon.

For a more detailed comparison of the total and endpoint specific hazard indices across study sites for anadromous fish species, see Appendix M. In this appendix, hazard indices are compared for the population with the highest exposure and non-cancer hazards - CRITFC's member tribal children with a high fish consumption rate (162 grams/day or about 5 meals per week).

Table 6-7 Summary of ranges in endpoint specific hazard indices across study sites for adults who consume anadromous fish species from the Columbia River Basin.

	Species	N	Reproductive/ Developmental And Central Nervous System	Immunotoxicty	Liver
			Non-cancer endpoints which most frequently exceed a hazard index of 1 for all species		
General Public-					
Average Fish Consumption					
	coho salmon	*3*	<1	<1	<1
	fall chinook salmon	*15*	<1	<1	<1
	spring chinook salmon	*24*	<1	<1	<1
	steelhead	*21*	<1	<1	<1
	eulachon	*3*	<1	<1	<1
	Pacific lamprey	*3*	<1	<1	<1
High Fish Consumption					
	coho salmon	*3*	2	3	<1
	fall chinook salmon	*15*	1 to 2	<1 to 3	<1
	spring chinook salmon	*24*	<1 to 6	1 to 2	<1
	steelhead	*21*	1 to 3	1 to 2	<1
	eulachon	*3*	<1	<1	<1
	Pacific lamprey	*3*	<1	9	<1
CRITFC's Member Tribal					
Average Fish Consumption					
	coho salmon	*3*	1	1	<1
	fall chinook salmon	*15*	<1 to1	1	<1
	spring chinook salmon	*24*	<1 to 3	<1	<1
	steelhead	*21*	<1 to 1	<1 to 1	<1
	eulachon	*3*	<1	<1	<1
	Pacific lamprey	*3*	<1	4	<1
High Fish Consumption					
	coho salmon	*3*	7	7	<1
	fall chinook salmon	*15*	3 to 6	<1 to 8	<1
	spring chinook salmon	*24*	<1 to 17	3 to 6	<1
	steelhead	*21*	4 to 8	3 to 6	<1
	eulachon	*3*	<1	<1	<1
	Pacific lamprey	*3*	<1	24	2

N= number of samples; All samples are fillet with skin except white sturgeon which is fillet without skin. Bridgelip sucker and eulachon are whole body fish samples.

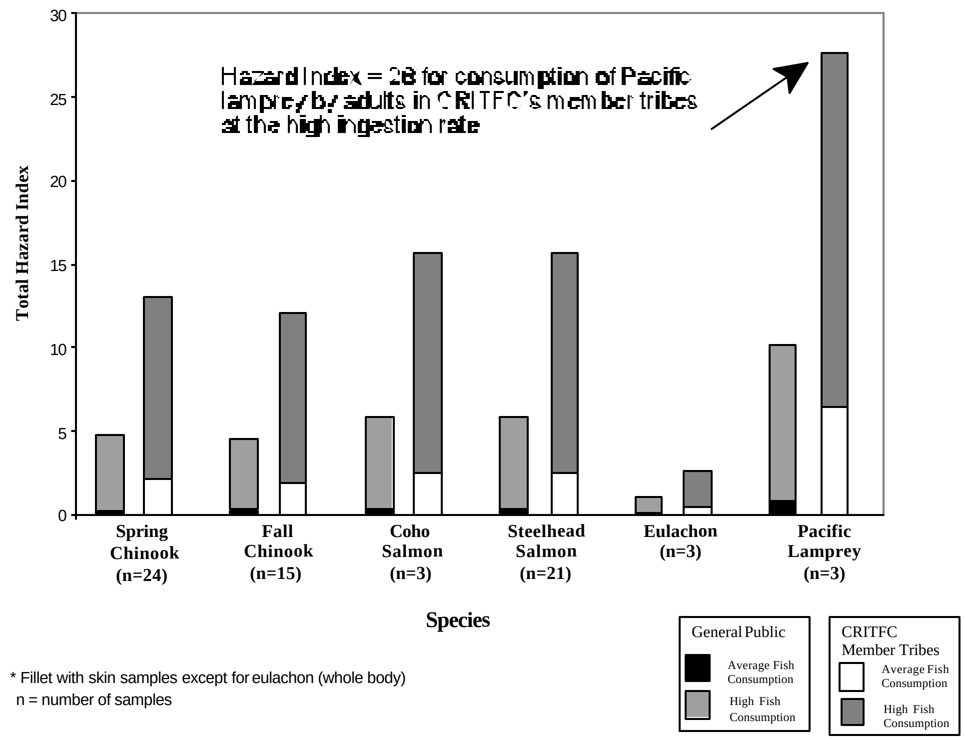


Figure 6.10 Adult total non-cancer indices for anadromous fish species*. Average concentrations for the Columbia River Basin.

Table 6-8 and Figures 6-11 through 6-16 show the major chemicals contributing to the total hazard index for each anadromous fish species (shown for basin-wide data, fillet with skin for all species except eulachon which was whole body). Aroclors and mercury were the primary chemicals of concern for non-cancer hazards for anadromous fish species, followed by arsenic. For eulachon, arsenic was the major contributor to non-cancer hazard. For Pacific lamprey, Aroclors contributed almost 87% to the non-cancer health effects.

Table 6-8. Percent contribution of contaminant groups to total non-cancer hazards for anadromous fish species. Based on Columbia River Basin-wide averages.

	spring chinook	coho salmon	eulachon	fall chinook	Pacific lamprey	steelhead
Number of samples	*24*	*3*	*3*	*15*	*3*	*21*
Tissue type	*FS*	*FS*	*WB*	*FS*	*FS*	*FS*
Total Metals	**65**	**54**	**95**	**58**	**7**	**55**
Mercury	43	41	ND	39	ND	43
Aluminum	<1	ND	2	<1	ND	<1
Arsenic	12	6	62	12	2	7
Cadmium	<1	ND	2	ND	1	<1
Chromium	3	2	ND	1	1	1
Copper	1	2	5	1	1	1
Selenium	3	2	12	3	2	2
Zinc	1	1	9	1	1	1
Other Metals	2	<1	2	<1	<1	<1
Total Aroclors	**34**	**45**	**ND**	**40**	**87**	**43**
Total Pesticides	**2**	**1**	**4**	**2**	**6**	**2**
Chlordane (total)	<1	<1	ND	<1	2	<1
Total DDT	2	1	4	2	4	1
Hexachlorobenzene	<1	ND	ND	<1	<1	<1

FS = fillet with skin; FW = fillet without skin; WB = whole body; ND= not detected

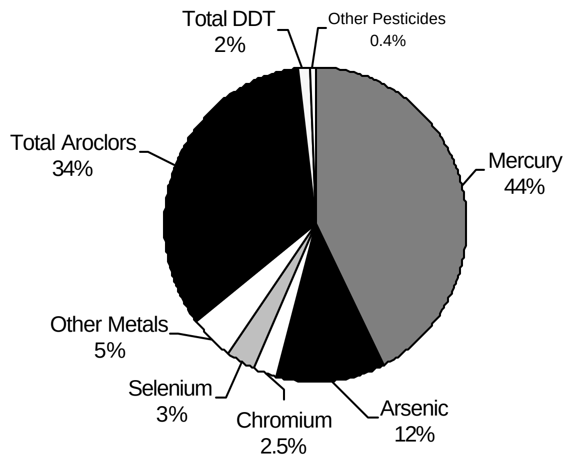


Figure 6-11. Percent contribution of basin-wide average chemical concentrations to non-cancer hazards from consumption of spring chinook fillet with skin. Number of samples = 24.

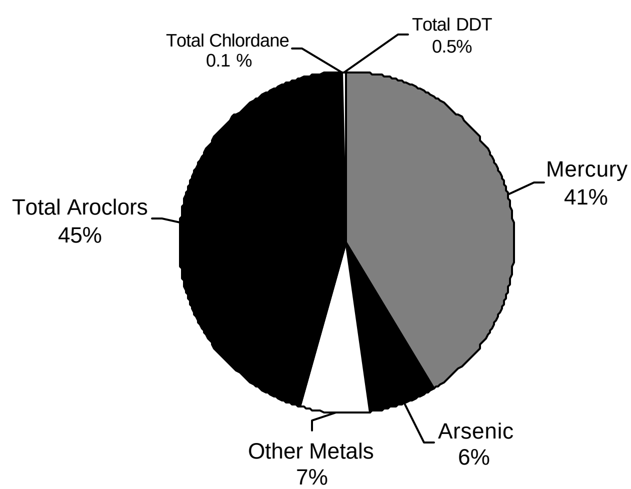


Figure 6-12. Percent contribution of basin-wide chemical concentrations to non-cancer hazards from consumption of coho salmon. Number of samples = 3.

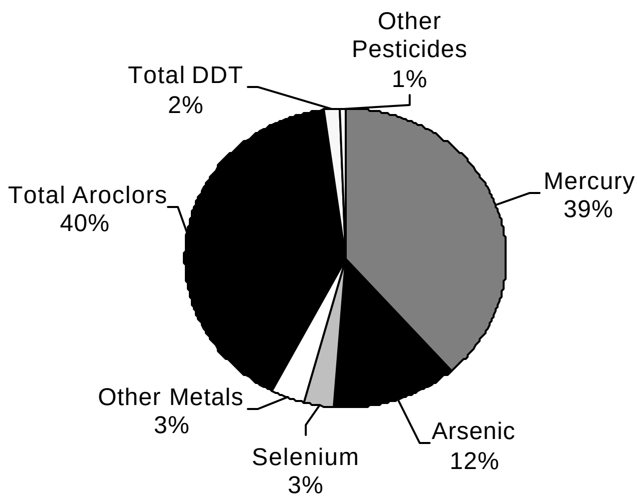


Figure 6-13. Percent contribution of basin-wide average chemical concentrations to non-cancer hazards from consumption of fall chinook fillet with skin. Number of samples = 15.

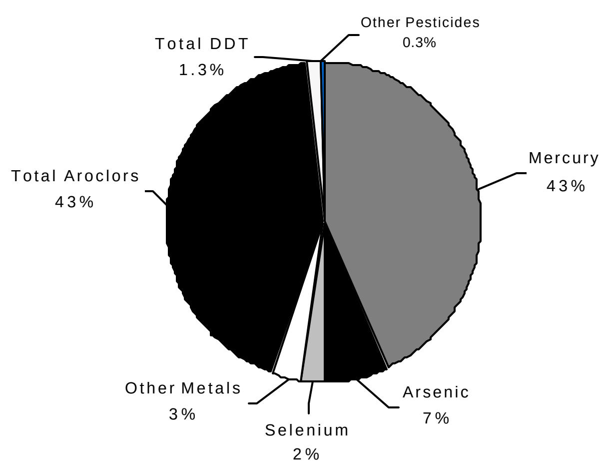


Figure 6-14. Percent contribution of basin-wide average chemical concentrations to non-cancer hazards from consumption of steelhead fillet with skin. Number of samples = 21.

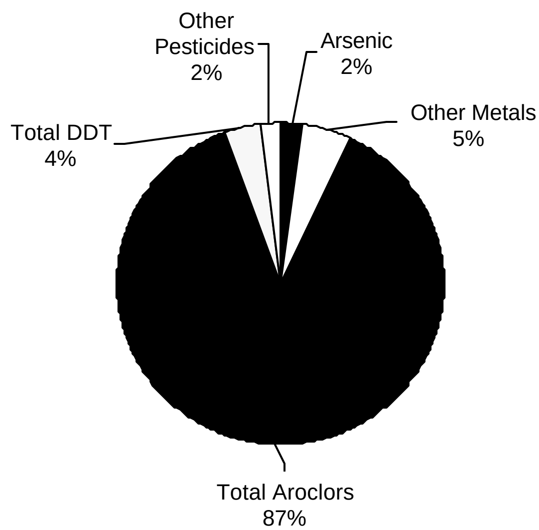


Figure 6-15. Percent contribution of basin-wide average chemical concentrations to non-cancer hazards from consumption of Pacific lamprey fillet with skin. Number of samples = 3.

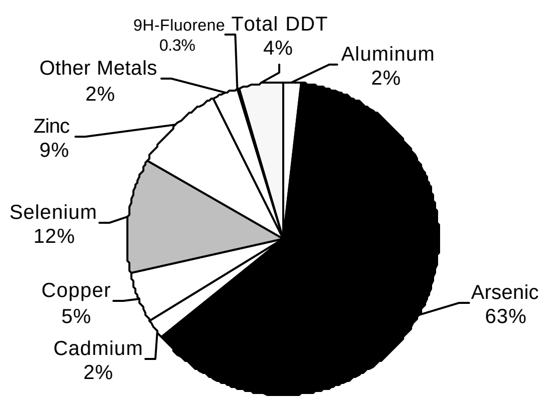


Figure 6-16. Percent contribution of basin-wide average chemical concentrations to non-cancer hazards from consumption of whole body eulachon. Number of samples =3.

6.2.1.3 Comparisons Between Anadromous Fish and Resident Fish Species

A comparison of the total hazard indices, endpoint specific hazard indices, and chemicals with hazard quotients greater than 1.0 among all of the fish species (resident fish and anadromous fish) can be made using the summary tables in Appendices O and P. The conclusions from these comparisons, are limited by the fact that different species were caught at different study sites and that sample numbers and sample types for each species varied.

- The endpoint specific hazard indices that were greater than 1 the most often and that had the highest values for all of the resident fish species were immunotoxicity, central nervous system, reproduction/developmental, and liver, with immunotoxicity usually having the highest endpoint specific hazard index. For resident fish species, endpoint specific hazard indices were rarely greater than 1 for children and adults in the general population with an average fish ingestion rate. The exceptions to this were white sturgeon and mountain whitefish caught in the Hanford Reach of the Columbia River (study site 9U), where endpoint specific hazard indices were greater than 1 (high of 2.7) for the endpoint of immunotoxicity. This was due to exposures to Aroclor greater than its reference dose.

- For salmon and steelhead, three of these endpoints were also the ones that also had the highest hazard indices: immunotoxicity, central nervous system, and reproduction/developmental, with most endpoints specific hazard indices being within a small range among the three salmon and steelhead (the exception is for the Klickitat due to mercury levels in spring chinook). No endpoint specific hazard indices were greater than 1 for children or adults in the general population with an average fish ingestion rate.

- For Pacific lamprey fillet with skin, the major contributor to non-cancer hazards was due to immunotoxicity; for whole body lamprey, it was immunotoxicity as well as central nervous system and reproduction/development endpoints (due to higher levels of mercury in whole body samples of lamprey). There were no endpoint specific hazard indices greater than 1 for the general population (adults or children) with an average fish consumption rate.

- For eulachon, only the endpoints of cardiovascular and hyperpigmentation/keratosis had hazard indices greater than 1 and only at the highest exposures (CRITFC's member tribal adults and children, high fish consumption).

Hazard indices greater than 1 for specific endpoints were primarily a result of elevated hazard quotients for a few chemicals: total Aroclors (immunotoxicity), mercury (central nervous system, and reproduction/developmental), total DDTs (liver), and arsenic (cardiovascular and hyperpigmentation/keratosis). This can be seen in the figures previously discussed for resident fish species (Figures 6-4 to 6-9) and anadromous fish species (Figures 6-11 to 6-16).

Although similar endpoint specific hazard indices were exceeded for many of the fish species tested, the magnitude of both the endpoint specific and total hazard indices vary substantially among the species. Table 6-9 shows a summary of the non-cancer results across all species at the high fish consumption rate for CRITFC's member tribal adults. All of the non-cancer endpoints that exceed 1.0 are shown for each species as are the range in total hazard indices across study sites and the total hazard index for the basin. For this table, fillet with skin data were used except for the species that had no fillet with skin samples (fillet without skin data for sturgeon and whole body for bridgelip sucker and eulachon).

Table 6-9. Summary of endpoint specific hazard indices and total hazard indices (by study site and basin-wide) for CRITFC's tribal member adult, high fish consumption.

			Non-cancer endpoints							
Species	N	Sample type	Central nervous system	Reproduction/ developmental	Immuno-toxicity	Liver	Cardio-vascular	Hyperpig-mentation	Range in study site total hazard indices	Total basin hazard index
Resident Species										
Bridgelip sucker	*3*	WB	2	2	17	6	<1	<1	27	27*
Largescale	*19*	FS	5 - 20	5 - 20	<1 - 21	1 - 7	<1	<1	10 - 45	29
Mt. whitefish	*12*	FS	<1 - 7	<1 - 7	4 - 140	<1 -	<1	<1	9 - 150	65
White sturgeon	*16*	FW	3 - 20	3 - 20	16 - 108	6 - 21	<1	<1	29 - 150	49
Walleye	*3*	FS	10	10	4	4	<1	<1	18	18*
Rainbow trout	*7*	FS	4, 5	4, 5	3, 4	<1	<1	<1	8, 10	9
Anadromous species										
Coho salmon	*3*	FS	7	7	7	<1	<1	<1	16	16*
Fall chinook	*15*	FS	3 -6	3 - 6	<1 - 8	<1	1 - 2	1 - 2	6 - 16	12
Spring chinook	*24*	FS	<1 - 17	<1 - 17	3 - 6	<1	2	2	6 - 24	13
Steelhead	*21*	FS	4 - 8	4 - 8	3 - 6	<1	1 - 2	1 - 2	9 - 15	16
Eulachon	*3*	WB	<1	<1	<1	<1	2	2	3	3*
Pacific lamprey	*3*	FS	<1	<1	24	2	<1	<1	28	28*

N= Number of samples; FW = fillet without skin; FS = fillet with skin, WB = whole body
*Columbia River Basin index based on study site.

A review of Table 6-9 (reference to study site specific information can be found in the tables in Appendices O and P) suggests that:

- For *eulachon*, all of the endpoint specific hazard indices were equal to or less than 2. The endpoint specific hazard indices were at or less than 2 for *Pacific lamprey* with the exception of a value of 24 for immunotoxicity. This was due to exposures greater than the reference dose for Aroclors. Total basin-wide hazard indices were 3 and 28, respectively, for eulachon and lamprey.

- For the *salmon and steelhead*, all of the study site endpoint specific hazard indices were 8 or less, except for one study site/species (hazard index of 17 for spring chinook for reproduction/development and central nervous system due to mercury in the sample from the Klickitat River). The total basin-wide hazard indices range from 12 to 16 for salmon and steelhead.

- For two of the resident fish species, *walleye* and *rainbow trout*, the endpoint specific hazard indices were at or less than 10. The endpoint specific hazard index for *bridgelip sucker* were less than 6, with the exception of immunotoxicity which had a value of 17. The total basin-wide hazard indices were 9, 18 and 27 for rainbow trout, walleye and bridgelip sucker, respectively.

- For *largescale sucker* the endpoint specific hazard indices for the central nervous system and reproductive/development range from 5 to 20 and for immunotoxicity from <1 to 21. The study site total hazard indices were from 10 to 45 with five of the six study site total hazard indices being greater than 20.

- The resident fish species, *mountain whitefish* and *sturgeon*, had the highest total study site hazard indices which ranged from 9 to 150 and 29 to 150, respectively. For the *whitefish*, total hazard indices were 9 (Umatilla), 13 (Deschutes), 72 (Yakima), and 150 (Hanford Reach of the Columbia, study site 9U)(see Table 3.1). The two highest values (72 for the Yakima and 150 for the Columbia at 9U) were due primarily to the high endpoint specific hazard indices for immunotoxicity (due to Aroclors) at these study sites. For *sturgeon*, all of the study site total hazard indices were greater than 20: hazard indices of 29 (Columbia at study sites 7 and 8); 40 (Columbia, study site 6); 46 (Snake, study site13); 62 (Columbia, study site 9L); and 150 (Columbia, study site 9U)(see Table 4.1). The high values for sturgeon were also in large part also due to exposures greater than the reference dose for Aroclors resulting in high endpoint specific hazard indices for immunotoxicity. It is obvious from Table 6-9 that for these 2 species (whitefish and sturgeon), their high endpoint specific hazard indices for immunotoxicity (due to total Aroclors) at some study sites tend to distinguish them from the other species.

Figure 6-17 is a summary of the total hazard indices for each species for all four ingestion rates for adults (general public adult, average and high fish consumption; CRITFC's member tribal adult, average and high fish consumption). Basin-wide fillet with skin data were used for this figure, except for those species that had only whole body samples (bridgelip sucker and eulachon) or fillet without skin (sturgeon) data. As can be seen from this table, the total hazard indices vary by species with white sturgeon and mountain whitefish having the highest total hazard indices among the 12 fish sampled. Largescale sucker, lamprey, and bridgelip sucker had similar but lower total hazard indices followed by the salmon, steelhead, and walleye, then rainbow trout and eulachon.

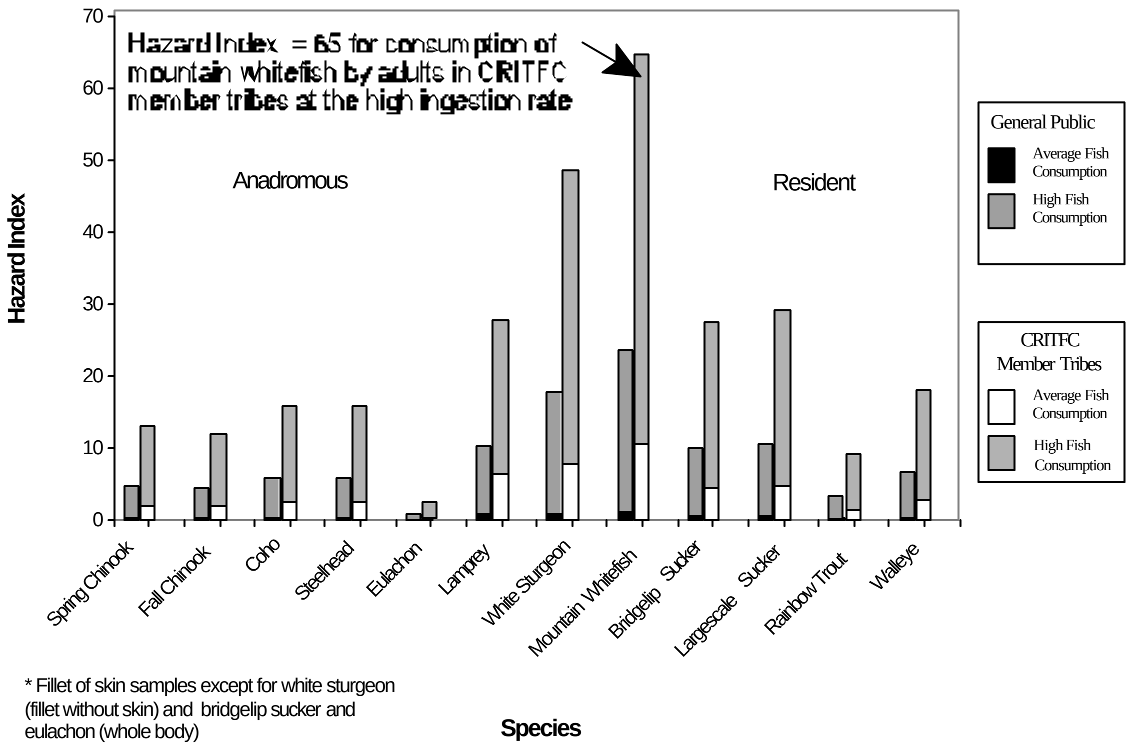


Figure 6-17. Adult total non-cancer hazard indices across all species*. Columbia River Basin data.

As was previously discussed for white sturgeon (Figures 6-2a-d), the estimated hazard indices for children were different than those for adults. For the general public, the hazard indices for children at the average fish ingestion were about 0.9 of those for adults at the average ingestion rate; the hazard indices for children at the high ingestion rate were about 1.3 times those for adults at the high ingestion rate. For CRITFC's member tribes, the hazard indices for children at the average and high ingestion rates were both about 1.9 times those for CRITFC's member tribal adults at the average and high ingestion rates, respectively.

Appendix M contains a comparison of the total and endpoint specific hazard indices across sites (anadromous and resident fish species) for CRITFC's member tribal children with a high ingestion rate. This was the population with the highest exposures and hazard indices.

6.2.2 Cancer Risk Evaluation

Because the incremental increase in cancer risks resulting from ingestion of fish was calculated for adults only, only four populations had cancer risk estimates: average and high fish consumption for both the general public adult and CRITFC's member tribal adult. However, for cancer risk, exposure duration does have an impact on the calculations. Therefore, risks were estimated for both 30 and 70 year exposure durations. This results in eight separate cancer risk calculations per study site and in the basin:

Average Fish Consumption

General public adult, 30 years	CRITFC's member tribal adult, 30 years
General public adult, 70 years	CRITFC's member tribal adult, 70 years

High Fish Consumption

General public adult, 30 years	CRITFC's member tribal adult, 30 years
General public adult, 70 years	CRITFC's member tribal adult, 70 years

The cancer risks calculated for each chemical for each study site are shown in Appendices I1 (general public and CRITFC's member tribal adults, 30 year exposure) and I2 (general public and CRITFC's member tribal adults, 70 year exposure). Appendix N shows the species specific cancer risks by study site over a range of fish ingestion rates. Appendices O and P, which were previously used for discussion of the non-cancer results, include summary results for the total cancer risk estimates by fish species and tissue type. Included in Appendices O and P are: (1) tables showing the total cancer risks by study site and basin for all 8 separate cancer risk calculations, and (2) tables showing the cancer risks by study site for those chemicals that were at or greater than a cancer risk of 1×10^{-5} for one population, CRITFC's member tribal adults, average fish consumption, 70 years exposure.

As with the non-cancer summary, a more detailed discussion of cancer risk will be done with one species, white sturgeon. This will be followed by a summary of the cancer risks for the rest of the resident fish species, the anadromous fish species, and finally, a summary across all species.

As previously discussed in Section 6.1.2, all of the cancer risks discussed in this risk characterization should be considered to be upper bound estimates of the increased risk of developing cancer as a result of fish consumption.

6.2.2.1 Cancer Risk Evaluation for Resident Fish

The potential cancer risks associated with consumption of fillet without skin and whole body white sturgeon were assessed by first calculating the risk for all detected chemicals with cancer slope factors (see Appendix I). These chemical specific risks in each sample were then summed to estimate the total cancer risk for a study site and for the basin. For sturgeon, these results are shown in Table 6-10.

Table 6-10. Summary of total estimated cancer risks for white sturgeon.

Consumption Rate/ Exposure Duration	Tissue Type	Total Excess Cancer Risk						
		Study Site [e]						Basin Average
		CR -6	CR -7	CR- 8	CR -9L	CR -9U	SR -13	
General Public[a,b]								
AFC/30-yr	FW	$4X10^{-5}$	$3X10^{-5}$	$4X10^{-5}$	$8X10^{-5}$	$1X10^{-4}$	$3X10^{-5}$	$5X10^{-5}$
	WB	na	na	$7X10^{-5}$	$6X10^{-5}$	$7X10^{-5}$	na	$7X10^{-5}$
HFC/30-yr	FW	$8X10^{-4}$	$6X10^{-4}$	$7X10^{-4}$	$1X10^{-3}$	$2X10^{-3}$	$6X10^{-4}$	$9X10^{-4}$
	WB	na	na	$1X10^{-3}$	$1X10^{-3}$	$1X10^{-3}$	na	$1X10^{-3}$
AFC/70-yr	FW	$9X10^{-5}$	$7X10^{-5}$	$8X10^{-5}$	$2X10^{-4}$	$3X10^{-4}$	$7X10^{-5}$	$1X10^{-4}$
	WB	na	na	$2X10^{-4}$	$1X10^{-4}$	$2X10^{-4}$	na	$2X10^{-4}$
HFC/70-yr	FW	$2X10^{-3}$	$1X10^{-3}$	$2X10^{-3}$	$3X10^{-3}$	$5X10^{-3}$	$1X10^{-3}$	$2X10^{-3}$
	WB	na	na	$3X10^{-3}$	$3X10^{-3}$	$3X10^{-3}$	na	$3X10^{-3}$
CRITFC's Tribal Member[c,d]								
AFC/30-yr	FW	$3X10^{-4}$	$3X10^{-4}$	$3X10^{-4}$	$6X10^{-4}$	$1X10^{-3}$	$3X10^{-4}$	$4X10^{-4}$
	WB	na	na	$6X10^{-4}$	$5X10^{-4}$	$6X10^{-4}$	na	$6X10^{-4}$
HFC/30-yr	FW	$2X10^{-3}$	$2X10^{-3}$	$2X10^{-3}$	$4X10^{-3}$	$6X10^{-3}$	$2X10^{-3}$	$3X10^{-3}$
	WB	na	na	$4X10^{-3}$	$3X10^{-3}$	$4X10^{-3}$	na	$3X10^{-3}$
AFC/70-yr	FW	$8X10^{-4}$	$6X10^{-4}$	$7X10^{-4}$	$1X10^{-3}$	$2X10^{-3}$	$6X10^{-4}$	$1X10^{-3}$
	WB	na	na	$1X10^{-3}$	$1X10^{-3}$	$1X10^{-3}$	na	$1X10^{-3}$
HFC/70-yr	FW	$5X10^{-3}$	$4X10^{-3}$	$4X10^{-3}$	$9X10^{-3}$	$1X10^{-2}$	$4X10^{-3}$	$6X10^{-3}$
	WB	na	na	$9X10^{-3}$	$7X10^{-3}$	$8X10^{-3}$	na	$8X10^{-3}$

AFC - average fish consumption HFC - high fish consumption FW - fillet without skin WB - whole body
na - not applicable; sample type not analyzed at this study site
[a] AFC risk based on average U.S. per capita consumption rate of uncooked freshwater and estuarine fish for general public of 7.5 g/day, or 1 8-oz meal per month (USEPA, 2000a).
[b] HFC risk based on 99th percentile U.S. per capita consumption rate of uncooked freshwater and estuarine fish for general public of 142.4 g/day, or 19 8-oz meals per month (USEPA, 2000a).
[c] AFC risk based on average consumption rate for fish consumers in the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin of 63.2 g/day, or 9 8-oz meals per month (CRITFC 1994).
[d] HFC risk based on 99th percentile consumption rate for fish consumers in the Umatilla, Nez Perce, Yakama, and Warm Springs Tribes of the Columbia River Basin of 389 g/day, or 53 8-oz meals per month (CRITFC 1994).
[e] Study site descriptions are in Table 1.1. CR = Columbia River; SR = Snake River

As can be seen from Table 6-10, for white sturgeon the total excess cancer risks range from a low of 3 X 10^{-5} in fillet without skin samples from the Columbia River (study site 7) and the Snake River (study site 13) assuming an average fish consumption rate and a 30 year exposure for the general population adult to a high of 1 X 10^{-2} in fillet without skin samples from the Columbia (study site 9U) assuming a high fish consumption rate and a 70 year exposure duration for CRITFC's member tribal adults.

The estimated upper bound cancer risks differ by study site for sturgeon since contaminant levels vary by study site (Table 6-10). For example, for one exposure - CRITFC's member tribal adult, average fish consumption, 30 year exposure - the ingestion of sturgeon (fillet without skin) from the Columbia River (study sites 6, 7 and 8) and the Snake River (study site 13) results in the same estimated cancer risk, 3 X 10^{-4}, while the risks estimated from consuming fish from the Columbia River, study site 9L (6 X 10^{-4}) and study site 9U (1 X 10^{-3}) were higher. This same difference was seen across all study sites (within a given sample type) for each of the exposure groups evaluated for cancer risk.

As previously discussed for non-cancer effects, the cancer risk at a given study site increases proportionally with increasing exposure. For cancer risks, exposures were lowest for the general public adult, average fish consumption, 30 years exposure and highest for CRITFC's member tribal adult, high fish consumption, 70 years exposure and depend both upon the exposure duration (30 or 70 year) and fish consumption rate. Table 6-11 shows the total cancer risks for all adult populations for white sturgeon (whole body) caught in the Columbia River at study site 8. Also shown are the ratios of the total cancer risks for the general public, average fish consumption at 30 years exposure to that of the other groups assessed in this risk assessment: CRITFC's member tribal adults with average and high fish consumption at both 30 and 70 years exposure; the general public adults with high fish consumption at 30 years exposure, and; the general public adults with average and high fish ingestion at 70 years exposure. As can be seen from this table, for whole body samples of sturgeon at Columbia River study site 8, the estimated upper bound cancer risk from eating fish was 7 X 10^{-5} for the general public, average fish consumption and 30 years exposure and 1 X 10^{-3} for the general public, high fish consumption and 30 years exposure. This was a difference of about 19 fold (when the rounding of the values in this table are accounted for). Likewise, the risks from eating sturgeon for the general public, average fish consumption and 70 years exposure was about 2 times higher than that for general public, average fish consumption and 30 years exposure.

Figure 6-18 shows the differences in cancer risks across sites for sturgeon (fillet without skin) for CRITFC member tribal adults and general public adults at the high fish consumption for both 30 and 70 year exposures. As can be seen, the cancer risks vary by site with the Hanford Reach of the Columbia River (site 9U) having the highest estimated risks.

Table 6-11. Comparison of estimated total cancer risks among adult populations

	Fish ingestion rate (grams/day)	Exposure duration (years)	Total cancer risk for adults for white sturgeon at Columbia River, study site 8 (whole body samples)	Approximate ratio of estimated cancer risks to that of general public with average fish consumption, 30 years exposure
General public	average (7.5)	30	7 X 10^{-5}	1
General public	high (142.4)	30	1 X 10^{-3}	19
CRITFC's member tribe	average (63.2)	30	6 X 10^{-4}	8
CRITFC's member tribe	high (389)	30	4 X 10^{-3}	52
General public	average (7.5)	70	2 X 10^{-4}	2
General public	high (142.4)	70	3 X 10^{-3}	44
CRITFC's member tribe	average (63.2)	70	1 X 10^{-3}	20
CRITFC's member tribe	high (389)	70	9 X 10^{-3}	121

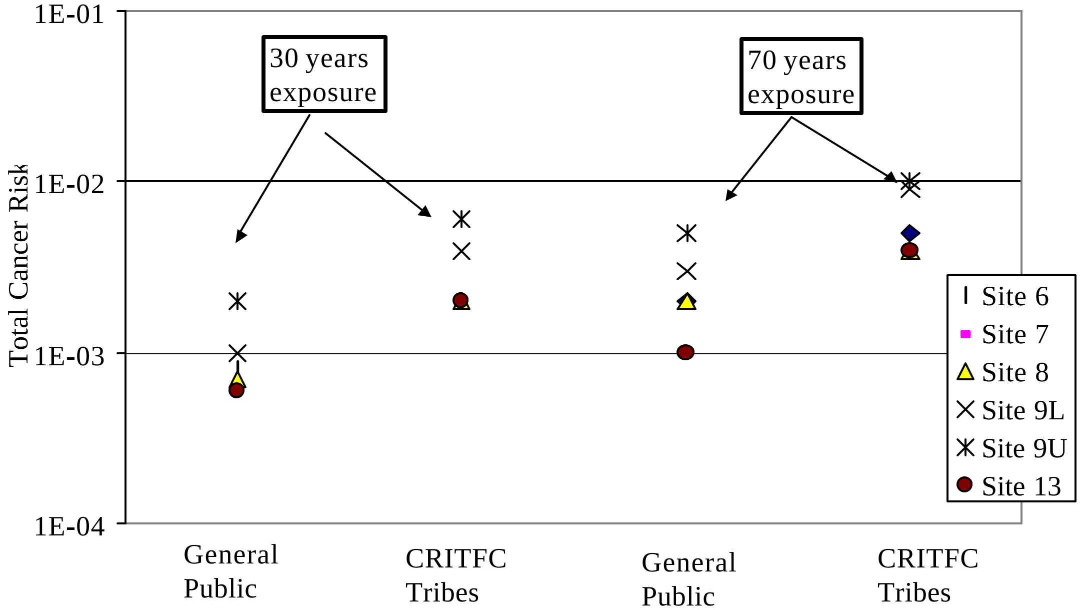


Figure 6-18. Comparison of estimated total cancer risks for consumption of white sturgeon across study sites for adults in the general public and CRITFC's member tribes at high consumption rates. Note that cancer risks for consumption of white sturgeon are the same for study sites 7 and 13.

Figure 6-19 shows the linear relationship between fish ingestion rate and estimated upper bound basin-wide cancer risk for adults for basin-wide average concentration of chemicals in white sturgeon fillet samples from the Columbia River Basin assuming both 30 and 70 years exposure duration. It also shows that cancer risks for a 70 year exposure were about 2 fold (i.e., 70 years/30 years = 2.3) higher than those for a 30 year exposure (see Appendix N for similar figures by study site and species).

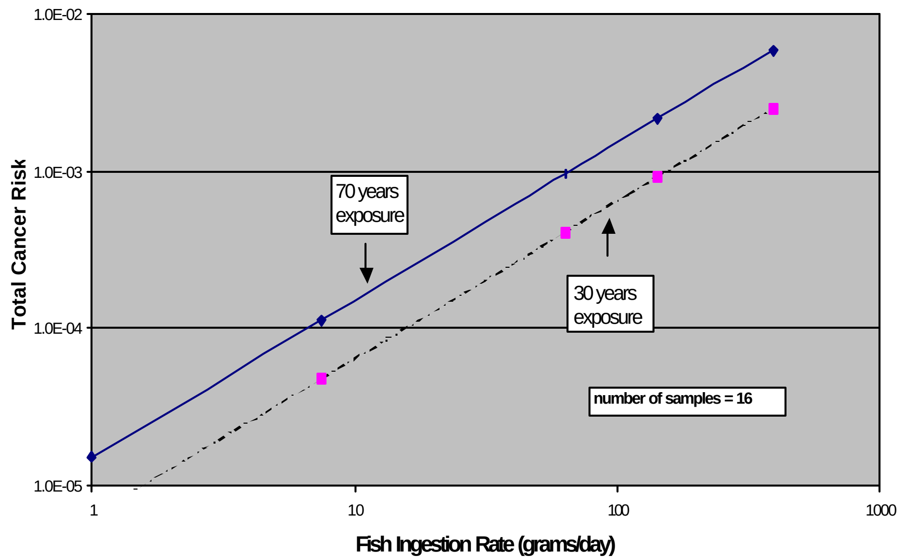


Figure 6-19. Total cancer risks versus fish consumption rate for adults. White sturgeon, basin-wide data (fillet with skin).

In the previous discussion on non-cancer results, it was shown that a small number of chemicals were responsible for most of the non-cancer health hazards from consuming fish. Tables 6-12 (fillet without skin) and Table 6-13 (whole body) show the chemicals with cancer risks at or greater than 1 X 10^{-5} for sturgeon for CRITFC's member tribal adults, average fish consumption and 70 years exposure duration. For cancer risks, a limited (but larger) number of chemicals were responsible for the majority of the cancer risk. These chemicals are:

- PCBs, including both Aroclors and dioxin-like PCB congeners,
- chlorinated dioxins and furans, with 2,3,7,8,-TCDF having the highest risk among the congeners,
- the pesticides aldrin, chlordane (total), DDD, DDE, and hexachlorobenzene, with DDE having the highest risk, and
- one metal, arsenic.

Not all chemicals were detected at every study site. For example, in the table with fillet without skin results (Table 6-12), Aroclors and PCB congeners 105, 118 and 156 were detected in all of the study site samples while other PCB congeners were detected at only one or two study sites.

Table 6-12. Chemicals with estimated cancer risks at or greater than 1 X 10^{-5} for white sturgeon, fillet without skin. CRITFC's member tribal adult, average fish consumption, 70 years exposure.

	Study Site*					
	CR - 6	**CR-7**	**CR -8**	**SR -13**	**CR - 9L**	**CR -9U**
PCBs						
Total Aroclors**	2 X 10^{-4}	1 X 10^{-4}	1 X 10^{-4}	1 X 10^{-4}	3 X 10^{-4}	7 X 10^{-4}
PCB 105	3 X 10^{-5}	2 X 10^{-5}	2 X 10^{-5}	3 X 10^{-5}	4 X 10^{-5}	1 X 10^{-4}
PCB 114	1 X10^{-5}	<	<	1 X 10^{-5}	2 X 10^{-5}	5 X 10^{-5}
PCB 118	3 X 10^{-5}	2 X 10^{-5}	2 X 10^{-5}	4 X 10^{-5}	5 X 10^{-5}	2 X 10^{-4}
PCB 126	<	2 X 10^{-5}	<	<	<	<
PCB 156	4 X 10^{-5}	3 X 10^{-5}	3 X 10^{-5}	5 X 10^{-5}	9 X 10^{-5}	2 X 10^{-4}
PCB 157	<	<	<	<	2 X 10^{-5}	5 X 10^{-5}
Dioxin/furans						
1,2,3,7,8-PeCDD	1 X 10^{-5}	2 X 10^{-5}	2 X 10^{-5}	1 X 10^{-5}	<	<
2,3,4,7,8-PeCDF	<	1 X 10^{-5}	2 X 10^{-5}	<	2 X 10^{-5}	2 X 10^{-5}
2,3,7,8-TCDD	4 X 10^{-5}	5 X10^{-5}	6 X 10^{-5}	5 X 10^{-5}	1 X 10^{-4}	3 X 10^{-5}
2,3,7,8-TCDF	2 X 10^{-4}	2 X10^{-4}	2 X 10^{-4}	6 X 10^{-5}	5 X 10^{-4}	3 X 10^{-4}
Pesticides						
Aldrin	<	<	<	<	2 X 10^{-5}	1 X 10^{-5}
Chlordane (total)	<	<	<	<	1 X 10^{-5}	2 X 10^{-5}
DDD	1 X 10^{-5}	1 X 10^{-5}	1 X 10^{-5}	1 X 10^{-5}	4 X 10^{-5}	8 X 10^{-5}
DDE	1 X 10^{-4}	1 X 10^{-4}	1 X 10^{-4}	1 X 10^{-4}	2 X 10^{-4}	4 X 10^{-4}
Hexachlorobenzene	<	<	<	<	2 X 10^{5}	<
Metals						
Arsenic	4 X 10^{-5}	5 X 10^{-5}	5 X 10^{-5}	3 X 10^{-5}	5 X 10^{-5}	4 X 10^{-5}
Total Cancer Risk for All Chemicals	8 X 10^{-4}	6 X 10^{-4}	7 X 10^{-4}	6 X 10^{-4}	1 X 10^{-3}	2 X 10^{-3}

"<" means that estimated cancer risk was less than 1 X 10^{-5} *Study site descriptions are in Table 1.1. CR = Columbia River; SR = Snake River
* * Based on "adjusted" Aroclor concentration (see Section 5.3.2)

Table 6-13. Chemicals with estimated cancer risks at or greater than 1 X 10^{-5} for white sturgeon, whole body. CRITFC's member tribal adult, average fish consumption, 70 years exposure.

		Study Site*	
	CR- 8	**CR -9L**	**CR- 9U**
PCBs			
Total Aroclors**	3 X 10^{-4}	2 X 10^{-4}	3 X 10^{-4}
PCB 105	6 X 10^{-5}	4 X 10^{-5}	5 X 10^{-5}
PCB 114	2 X 10^{-5}	2 X 10^{-5}	2 X 10^{-5}
PCB 118	7 X 10^{-5}	5 X 10^{-5}	5 X 10^{-5}
PCB 156	1 X 10^{-4}	9 X 10^{-5}	9 X 10^{-5}
PCB 157	2 X 10^{-5}	2 X 10^{-5}	2 X 10^{-5}
Dioxin/furans			
2,3,4,7,8-PeCDF	2 X 10^{-5}	3 X 10^{-5}	2 X 10^{-5}
2,3,7,8-TCDD	9 X 10^{-5}	1 X 10^{-4}	9 X 10^{-5}
2,3,7,8-TCDF	3 X 10^{-4}	3 X 10^{-4}	4 X 10^{-4}
Pesticides			
Aldrin	<	2 X 10^{-5}	2 X 10^{-5}
Chlordane (total)	<	1 X 10^{-5}	<
DDD	2 X 10^{-5}	3 X 10^{-5}	5 X 10^{-5}
DDE	2 X 10^{-4}	2 X 10^{-4}	2 X 10^{-4}
Hexachlorobenzene	<	2 X 10^{-5}	1 X 10^{-5}
Metals			
Arsenic	7 X 10^{-5}	4 X 10^{-5}	4 X 10^{-5}
Total Cancer Risk for All Chemicals	1 X 10^{-3}	1 X 10^{-3}	1 X 10^{-3}

"<" means that estimated cancer risk was less than 1 X 10^{-5}. CR = Columbia River
*Study site descriptions are in Table 1-1. **Based on "adjusted Aroclor concentration (see Section 5.3.2)

The total cancer risk estimates and the summary of chemicals with risks at or greater than 1 X 10^{-5} for other resident fish species are provided in Appendix O by species: Tables 1.3 and 1.4 (bridgelip sucker), 2.3 and 2.4 (largescale sucker), 3.3 and 3.4 (mountain whitefish), 4.3 and 4.4 (white sturgeon), 5.3 and 5.4 (walleye), and 6.3 and 6.4 (rainbow trout). Table 6-14 shows a summary of the total cancer risk estimates for the resident fish species for one adult population - CRITFC's member tribal adults with an average fish consumption and 70 years exposure. Results of the fillet with skin samples are shown, except for sturgeon (only fillet without skin sampled) and bridgelip sucker (only whole body sampled).

Table 6-14. Summary of estimated total cancer risks by study site and basin-wide, resident fish species. CRITFC's tribal member adult, average fish consumption, 70 years exposure

Species	N	Sample type	Study site name	Study Site	Study site cancer risk	Range in study site cancer risks	Basin cancer risk
Bridgelip sucker	*3*	WB	Yakima	48	5 X 10^{-4}	5 X 10^{-4}	5 X 10^{-4}*
Largescale sucker	*19*	FS	Columbia	9U	6 X 10^{-4}	1 to 6 X 10^{-4}	4 X 10^{-4}
			Deschutes	98	1 X 10^{-4}		
			Umatilla	30	2 X 10^{-4}		
			Snake	13	2 X 10^{-4}		
			Yakima	48	4 X 10^{-4}		
			Yakima	49	3 X 10^{-4}		
Mountain whitefish	*12*	FS	Columbia	9U	4 X 10^{-3}	1 X 10^{-4} to 4 X 10^{-3}	1 X 10^{-3}
			Deschutes	98	3 X 10^{-4}		
			Umatilla	101	1 X 10^{-4}		
			Yakima	48	1 X 10^{-3}		
White sturgeon	*16*	FW	Columbia	6	8 X 10^{-4}	6 X 10^{-4} to 2 X 10^{-3}	1 X 10^{-3}
			Columbia	7	6 X 10^{-4}		
			Columbia	8	7 X 10^{-4}		
			Columbia	9L	1 X 10^{-3}		
			Columbia	9U	2 X 10^{-3}		
			Snake	13	6 X 10^{-4}		
Walleye	*3*	FS	Umatilla	30	2 X 10^{-4}	2 X 10^{-4}	2 X 10^{-4}*
Rainbow trout	*7*	FS	Deschutes	98	2 X 10^{-4}	2 X 10^{-4}	2 X 10^{-4}
			Yakima	49	2 X 10^{-4}		

N= number of samples; WB = whole body; FS = fillet with skin; FW = fillet without skin
* Basin-wide cancer risk based on one study site

White sturgeon and mountain whitefish had the highest estimated basin-wide cancer risks at 1 X 10^{-3} (Table 6-14). All of the white sturgeon study site cancer risks were at or greater than 6 X 10^{-4} with a high of 2 X 10^{-3}. The highest cancer risks for sturgeon were from consuming fish from the Columbia River at study sites 9L (1 X 10^{-3}) and 9U (2 X 10^{-3}). The four mountain whitefish study sites span more than an order of magnitude in cancer risk - 1 X 10^{-4} for the Umatilla (study site 101), 3 X 10^{-4} for the Deschutes (study site 98), 1 X 10^{-3} for the Yakima (study site 48), and 4 X 10^{-3} for the Columbia River (study site 9U). Cancer risks were highest for the Yakima (study site 48) and Columbia River (study site 9U) for whitefish and for the Columbia River at study sites 9U and 9L for sturgeon.

Bridgelip sucker (one study site at 5 X 10^{-4}) and largescale sucker (six study sites ranging from 1 to 6 X 10^{-4}) had the next highest basin-wide cancer risks, 5 X 10^{-4} and 4 X 10^{-4}, respectively. Walleye (one study site at 2 X 10^{-4}) and rainbow trout (two study sites at 2 X 10^{-4}) had the lowest basin-wide cancer risks.

Figure 6-20 summarizes the total basin-wide cancer risks for resident fish species for adults using high and average fish consumption rates for the general public and for CRITFC's member tribal populations assuming 70 years exposure duration. Note that the Y axis is on a logarithmic scale and that each bar begins at 0 on the Y axis. For example, the cancer risk for mountain whitefish for the general public adult, high fish consumption for 70 years, is 3 X 10^{-3}; for CRITFC member tribal adults, high fish consumption for 70 years, the cancer risk estimates is 8 X 10^{-3}. As with Table 6-14, this figure shows that consumption of mountain whitefish and white sturgeon result in the highest cancer risks, followed by sucker, rainbow trout, and walleye. It also shows that for all species, the total cancer risks were highest for CRITFC's member tribal adults at the high fish ingestion rates (389 g/day) followed by the general public adult, high ingestion rate (142.4 g/day); CRITFC's member tribal adult, average ingestion rate (63.2 g/day); and general public adult, average ingestion rate (7.5 g/day).

For a more detailed comparison of cancer risks across resident fish species for each study site, see Appendix N. In this appendix, cancer risks are shown over a range of ingestion rates for all species caught at a study site.

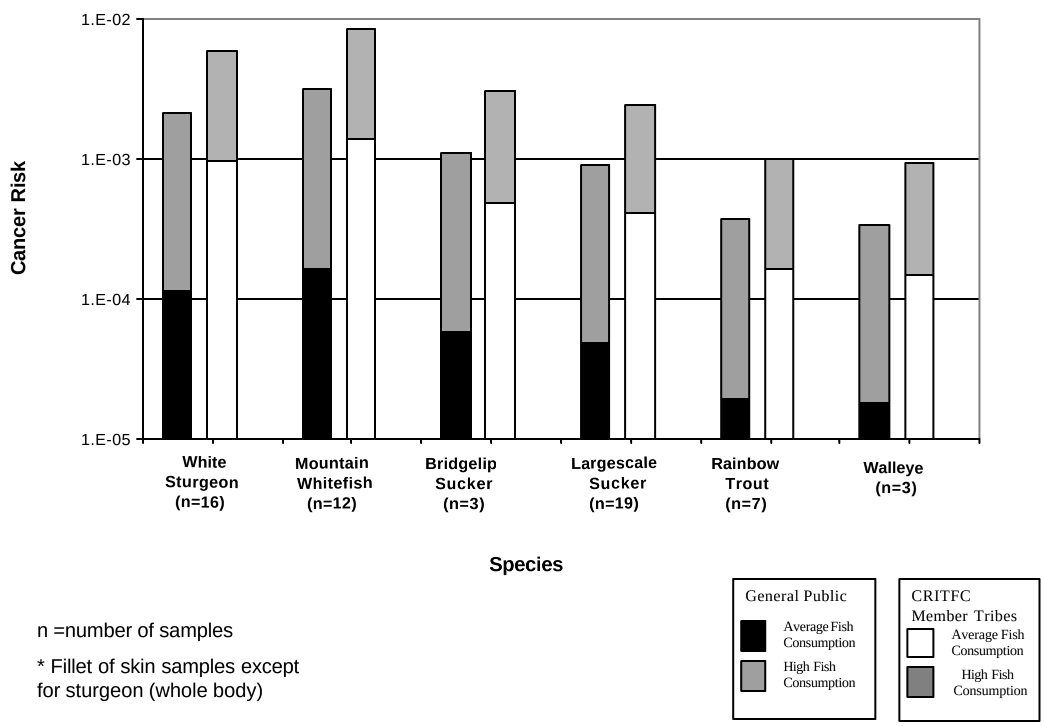


Figure 6-20. Adult cancer risks for resident fish species*. Columbia River Basin data (70 years exposure).

The chemicals with cancer risks equal to or greater than 1 X 10^{-5} for resident fish species are shown in Appendix O for CRITFC's member tribal adults for the average fish consumption rate and 70 years exposure (Tables 1.4 (bridgelip sucker), 2.4.1 and 2.4.2 (largescale sucker), 3.4.1 and 3.4.2 (mountain whitefish), 4.4.1 and 4.4.2 (white sturgeon), 5.4.1 and 5.4.2 (walleye), and 6.4.1 and 6.4.2 (rainbow trout).

In general, four chemical classes (PCBs, chlorinated dioxins and furans, pesticides and metals) were responsible for the cancer risks at or greater than 1 X 10^{-5} for all of the resident fish species. The exception to this was two study site samples for largescale sucker: the Snake River (study site 13, fillet with skin) had 2 semivolatiles at or greater than a 1 X 10^{-5} cancer risk, dibenz(a,h)anthracene and benzo(a)pyrene, and the Yakima River (study site 49, whole body) had one, 1,2-diphenylhydrazine.

For the metals, only one of the contaminants detected, inorganic arsenic, had an oral cancer slope factor. Thus, inorganic arsenic was the only detected metal for which cancer risks were estimated.

For the three other classes of chemicals contributing the most to the cancer risk (PCBs, dioxins/furans, and pesticides), the chemicals within each class that were at or greater than 1 X 10^{-5} vary among species and sometimes among different sample types of the same species. For example, the pesticide, hexachlorobenzene, was found at a level greater than 1 X 10^{-5} risk in only three white sturgeon samples: at Columbia River study site 9L for fillet without skin and at Columbia River study sites 9L and 9U for whole body samples. Aldrin was found at a cancer risk greater than 1 X 10^{-5} in only 2 species: at the Columbia River, study sites 9L and 9U, for both types of sturgeon samples (fillet without skin and whole body); and at Columbia River study site 9U for whitefish samples (whole body and fillet with skin).

All study sites and species had total Aroclors at or greater than a risk of 1 X 10^{-5} except for the Snake River (study site 13) for largescale sucker (fillet with skin). Up to seven different PCB congeners (105, 114, 118, 126, 156, 157 and 169) were found at or greater than a risk of 1 X 10^{-5} with the number per study site varying from zero to seven at different study sites. Up to four dioxins/furans (2,3,7,8-TCDF, 2,3,4,7,8-PCDF, 2,3,7,8-TCDD and 1,2,3,7,8-PCDD) were at or greater than a cancer risk of 1 X 10^{-5} with the number varying from two to four per study site.

Table 6-15 and Figures 6-21 through 6-26 show the percent contribution to total cancer risk from each chemical and class of chemical using the basin-wide cancer risk data for resident fish (fillet with skin for all species except sturgeon (fillet without skin) and bridgelip sucker (whole body).

Table 6-15. Percent contribution of contaminant groups to estimated cancer risks for resident fish species. Based on Columbia River Basin-wide averages.

	White Sturgeon	Largescale Sucker	Mountain Whitefish	Walleye	Rainbow Trout	Bridgelip Sucker
Tissue Type	*FW*	*FS*	*FS*	*FS*	*FS*	*WB*
Number of Samples	*16*	*19*	*12*	*3*	*7*	*3*
Total Metals	**4**	**2**	**1**	**33**	**ND**	**8**
Arsenic	4	2	1	33	ND	8
Total PCBs/Aroclors	**39**	**46**	**83**	**31**	**68**	**46**
PCB 105	3	2	6	3	4	2
PCB 114	1	1	2	1	2	1
PCB 118	4	6	15	6	9	3
PCB 126	2	9	18	ND	29	14
PCB 156	6	6	12	6	8	4
PCB 157	1	1	2	ND	2	ND
PCB 169	ND	2	<1	ND	ND	1
Other PCBs	<1	<1	1	<1	<1	<1
Total Aroclors*	21	19	26	15	15	22
Total Semi-Vocatives	**ND**	**28**	**ND**	**ND**	**ND**	**1**
1,2-Diphenylhydrazine	ND	ND	ND	ND	ND	1
Benzo(a)pyrene	ND	8	ND	ND	ND	ND
Dibenz[a,h]anthracene	ND	17	ND	ND	ND	ND
Indeno(1,2,3-cd)pyrene	ND	2	ND	ND	ND	ND
Other Semi-Vocatives	ND	2	ND	ND	ND	ND
Total Pesticides	**23**	**21**	**10**	**11**	**5**	**32**
Aldrin	2	ND	2	ND	ND	ND
DDD	2	1	1	1	<1	3
DDE	15	16	8	10	4	25
DDT	<1	2	<1	<1	1	3
Heptachlor Epoxide	1	ND	ND	ND	ND	ND
Hexachlorobenzene	1	ND	<1	ND	ND	ND
Other Pesticides	2	2	<1	ND	<1	<1
Total Dioxins/Furans	**36**	**5**	**8**	**26**	**29**	**13**
2,3,4,6,7,8-HxCDF	<1	<1	<1	1	2	<1
2,3,4,7,8-PeCDF	1	<1	1	1	2	2
2,3,7,8-TCDD	7	1	1	7	6	2
2,3,7,8-TCDF	26	1	5	6	2	3
OCDD	<1	<1	<1	<1	<1	<1
OCDF	<1	<1	<1	ND	<1	<1
1,2,3,7,8-PeCDD	1	2	2	7	13	5
1,2,3,4,7,8-HxCDD	<1	<1	<1	1	1	<1
other dioxins	1	1	<1	2	4	1

ND=Not detected; *Based on adjusted Aroclor concentration (See Section 5.3.2)

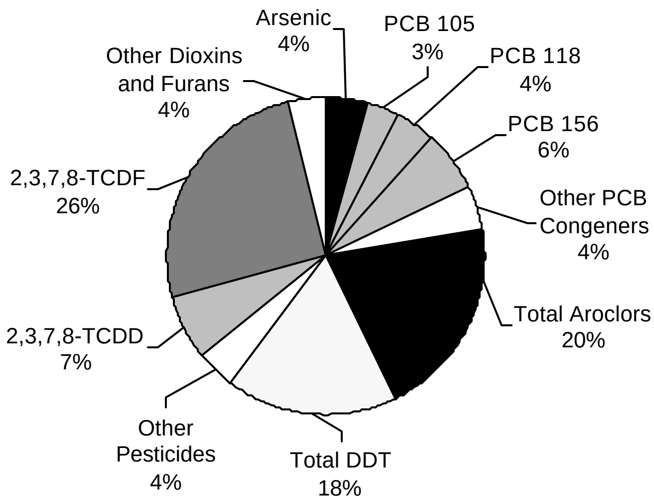


Figure 6-21. Percent contribution of basin-wide average chemical concentrations to cancer risk from consumption of white sturgeon fillet without skin. Number of samples = 16.

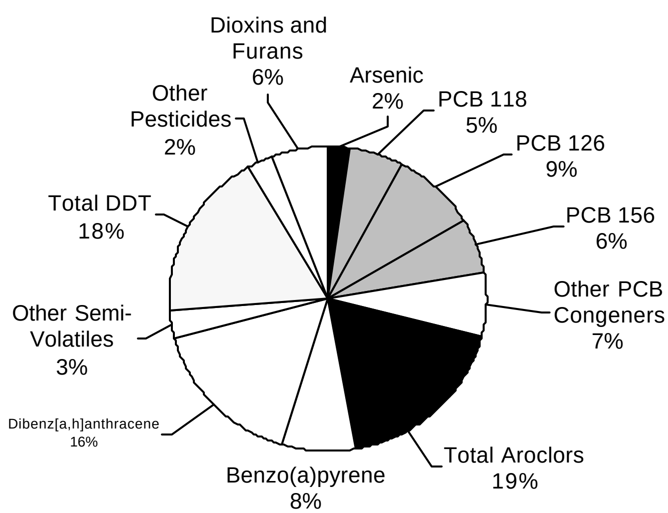


Figure 6-22. Percent contribution of basin-wide average chemical concentrations to cancer risk from consumption of largescale sucker fillet with skin. Number of samples = 19.

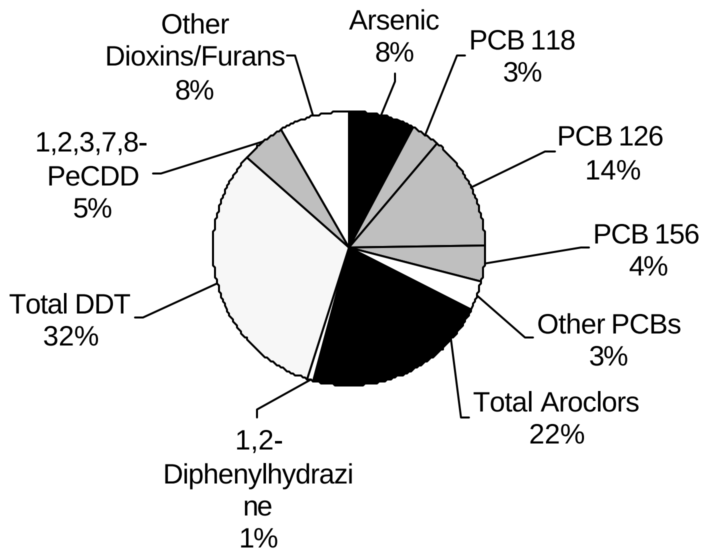


Figure 6-23. Percent contribution of basin-wide average chemical concentrations to cancer risk from consumption of whole body bridgelip sucker. Number of samples = 3.

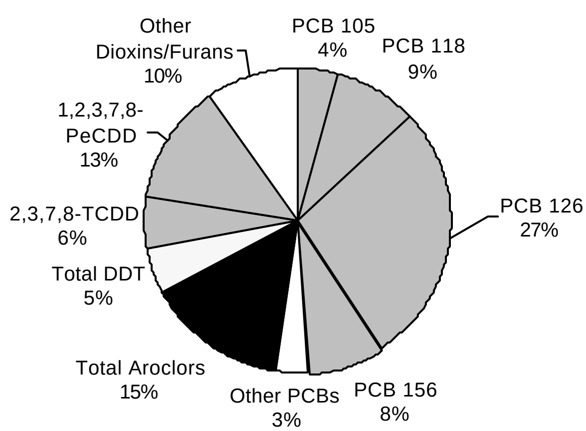


Figure 6-24. Percent contribution of basin-wide average chemical concentrations to cancer risk from consumption of rainbow trout fillet with skin. Number of samples = 7.

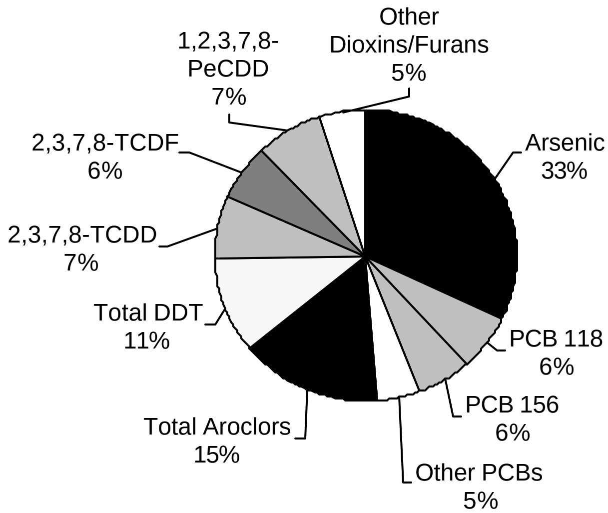


Figure 6-25. Percent contribution of basin-wide average chemical concentrations to cancer risk from consumption of walleye fillet with skin. Number of samples =3.

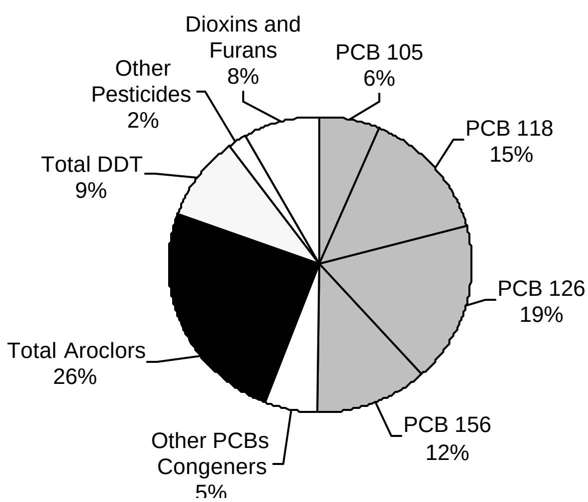


Figure 6-26. Percent contribution of basin-wide average chemical concentrations to cancer risk from consumption of mountain whitefish fillet with skin. Number of samples = 12.

For all of the resident fish species except walleye, the majority of the cancer risk was from dioxins and furans, a small number of pesticides and PCBs. (Table 6-15 and Figures 6-21 through 6-26). Inorganic arsenic contributes to about 33% of the cancer risk for walleye.

- Chlorinated dioxins and furans contribute from 5% of the total cancer risk for largescale sucker to 36% for sturgeon. For sturgeon, 2,3,7,8-TCDF was by far the largest contributor of the dioxins/furans. For some of the other species, other congeners (e.g., 2,3,7,8-TCDD and 1,2,3,7,8-PeCDD) were contributors to the dioxin/furan cancer risk.

- Pesticides contribute from about 5% to 32% of the total cancer risk, with DDE contributing more than any other pesticide.

- PCBs (both total Aroclors and dioxin-like congeners) contribute from 31% to 83% of the total cancer risk. The contribution from Aroclors (primarily 1254 and 1260) to the cancer risk for this class of chemicals was approximately 15% for rainbow trout, 26% for mountain whitefish, 19% for largescale sucker, 22% for bridgelip sucker, 15% for walleye, and 21% for sturgeon. The contribution to PCB cancer risk from the dioxin-like PCB congeners ranges from a low of 17% for walleye to a high of 56% for mountain whitefish.

- The contribution from inorganic arsenic to total cancer risk was from 0% (not detected in rainbow trout fillets) to 33% for the resident fish species. For most species, the value was less than 8%. The exception was walleye at 33%.

6.2.2.2 Cancer Risk Evaluation for Anadromous Fish

The total cancer risk estimates for the anadromous fish species are provided in Appendix P by species: Tables 1.3 (coho salmon), 2.3 (fall chinook salmon), 3.3 (spring chinook salmon), 4.3 (steelhead), 5.3 (eulachon), and 6.3 (Pacific lamprey).

Table 6-16 summarizes the estimates of the total cancer risks for anadromous fish species by study site and by basin for CRITFC's member tribal adults, average consumption rate (63.2 g/day), and 70 years exposure. Fillet with skin data are shown except for eulachon, which had only whole body samples collected. Figure 6-27 shows the relative differences in cancer risks for anadromous fish species using average and high fish consumption rates for the general public and CRITFC's member tribal adult assuming 70 years exposure. Note that the Y axis is on a logarithmic scale and that all of the bars begin at 0 on the Y axis. For example, the cancer risk for Pacific lamprey for the general public adult, high fish consumption for 70 years, is slightly greater than 1 X 10^{-3}; for CRITFC member tribal adults, high fish consumption for 70 years, the cancer risk estimates is 4 X 10^{-3}. Columbia River Basin data are shown for all species (for coho salmon, eulachon and Pacific lamprey, only one study site was sampled).

Table 6-16. Summary of estimated total cancer risks by study site and basin-wide, anadromous fish species CRITFC's tribal member adult, average fish consumption, 70 years exposure

Species	N	Sample type	Study site name	Study site #	Study site cancer risk	Range in study site cancer risks	Basin cancer risk
Coho salmon	*3*	FS	Umatilla	30	2×10^{-4}	2×10^{-4}	$2 \times 10^{-4*}$
Fall chinook salmon	*15*	FS	Columbia	8	2×10^{-4}	1 to 2×10^{-4}	2×10^{-4}
			Columbia	14	2×10^{-4}		
			Klickitat	56	2×10^{-4}		
			Umatilla	30	1×10^{-4}		
			Yakima	48	2×10^{-4}		
Spring chinook salmon	*24*	FS	Willamette	21	2×10^{-4}	2 to 3×10^{-4}	2×10^{-4}
			Wind River	63	2×10^{-4}		
			Little White Salmon	62	2×10^{-4}		
			Klickitat	56	2×10^{-4}		
			Looking Glass Creek	94	2×10^{-4}		
			Umatilla	30	3×10^{-4}		
			Yakima	48	2×10^{-4}		
			Icicle Creek	51	2×10^{-4}		
Steelhead	*21*	FS	Columbia	8	1×10^{-4}	1 to 3×10^{-4}	2×10^{-4}
			Hood River	25	3×10^{-4}		
			Klickitat	56	2×10^{-4}		
			Snake River	93	2×10^{-4}		
			Clearwater	96	3×10^{-4}		
			Yakima	48	2×10^{-4}		
Eulachon	*3*	WB	Columbia	3	2×10^{-4}	2×10^{-4}	$2 \times 10^{-4*}$
Pacific lamprey	*3*	FS	Willamette	21	6×10^{-4}	6×10^{-4}	$6 \times 10^{-4*}$

N= Number of Samples WB = whole body; FS = fillet with skin
* Basin-wide cancer risks based on one study site

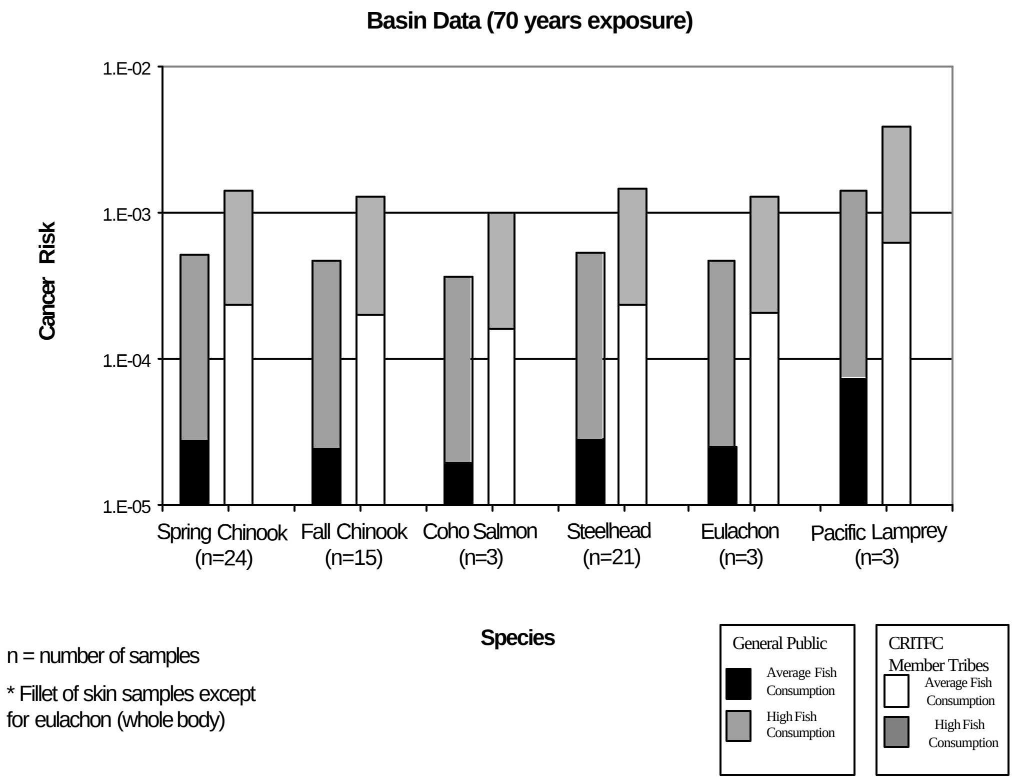


Figure 6-27. Adult cancer risks for anadromous fish species*. Columbia River Basin-wide average data (70 years exposure).

For coho salmon, fall chinook salmon, spring chinook salmon, steelhead and eulachon, the study site cancer risks were all within a range of 1 X 10^{-4} to 3 X 10^{-4} and the basin-wide risks were at approximately 2 X 10^{-4}. The estimated cancer risk from consumption of Pacific lamprey was 6 X 10^{-4} (Table 6-16).

For all species, the total cancer risks were highest for CRITFC's member tribal adults at the high fish ingestion rates (389 g/day) followed by the general public, high ingestion rate (142.4 g/day); CRITFC's member tribal adult, average ingestion rate (63.2 g/day); and general public, average ingestion rate (7.5 g/day) (Figure 6-27).

For a more detailed comparison of cancer risks across anadromous fish species for each study site, see Appendix N. In this appendix, estimated cancer risks are shown for all species caught at a study site for a range of ingestion rates.

The chemicals with risks at or greater than 1 X 10^{-5} for each species for CRITFC's member tribal adults with average fish consumption and 70 years exposure are summarized in Appendix P by species. A review of this appendix shows that:

- For steelhead, spring chinook salmon, and fall chinook salmon, the same three chemical classes (PCBs, dioxins/furans, and one inorganic, arsenic) were responsible for the majority of the risks at or greater than 1 X 10^{-5}. Fillet with skin and whole body samples of coho had no risks greater than 10^{-5} for dioxins and furans while whole body samples had a 1 X 10^{-5} risk for DDE. For spring and fall chinook salmon and steelhead, which had dioxins and furans risks at or greater than1 X 10^{-5}, three congeners were greater than this risk level - 1,2,3,7,8-PCDD; 2,3,4,7,8-PCDF; and 2,3,7,8-TCDF. For steelhead and all three salmon, Aroclors and PCB congeners 126 and 118 were found at all study sites at or greater than 1 X 10^{-5}, as was inorganic arsenic.

- Eulachon was sampled at only one site (Columbia River, study site 3). Risks from consumption of the whole body composite sample were at or greater than 1 X 10^{-5} for two chemicals, arsenic and 1,2,3,7,8-PCDD.

- Pacific lamprey collected at two sites -Willamette Falls (21) and Fifteen Mile Creek (24) - had risks at or greater than 1 X 10^{-5} for four classes of chemicals: PCBs (Aroclors as well as PCBs 105,114,118,126, and 156); chlorinated dioxins/furans (1,2,3,7,8-PCDD and 2,3,7,8-TCDF); metals (inorganic arsenic); and pesticides (total chlordane, DDT, DDE and hexachlorobenzene).

Tables 6-17 and Figures 6-28 through 6-33 show the percent contribution to total cancer risk for each chemical and/or chemical class using basin-wide cancer risk data (based on fillet of skin data for all species except eulachon which was whole body).

A review of Table 6-17 and Figures 6-28 through 6-33 shows that:

- Arsenic contributes from 33 to 54% of the total cancer risk for salmon and steelhead; 58% for eulachon; and only about 7% for lamprey.

- PCBs (Aroclors and dioxin-like congeners) contribute from 32 to 50% of the total cancer risk for the salmon and steelhead, 77% for lamprey, and only 4% for eulachon. For the salmon, steelhead, and lamprey, Aroclors contribute from 12 to 28% of the total cancer risk. Aroclors were not detected in eulachon. Nine different PCB congeners were detected with PCB 126 contributing the most to total cancer risk (from 6 to 35%) for all species except eulachon. PCB 126 was not detected in eulachon.

- The percent contribution from all pesticides was from about 1 to 9% of the risk.

- The contribution to total cancer risk for chlorinated dioxins and furans was from 9 to 14% for all species except eulachon. For eulachon, the percent contribution to total cancer risk is about 36%.

- Salmon and steelhead look very similar in that arsenic and PCBs were the major contributors to cancer risk followed by dioxin/furans and then pesticides. For Pacific lamprey, PCBs were the major risk contributor at 77% with the rest of the risk split between arsenic, dioxin/furans and pesticides. Most of the risk for eulachon is from arsenic, then dioxins/furans with less than 4% from PCBs and pesticides combined.

Table 6-17. Percent contribution of contaminant groups to cancer risk for anadromous fish species. Based on Columbia River Basin-wide averages.

	Spring Chinook Salmon	**Coho Salmon**	**Fall Chinook Salmon**	**Steelhead**	**Pacific Lamprey**	**Eulachon**
Tissue Type	*FS*	*FS*	*F S*	*FS*	*FS*	*WB*
Number of samples	*24*	*15*	*3*	*21*	*3*	*3*
Total Metals	**50**	**45**	**54**	**33**	**7**	**58**
Arsenic	50	45	54	33	7	58
Total PCB/Aroclors	**32**	**43**	**32**	**50**	**77**	**4**
PCB 105	1	3	2	1	3	1
PCB 114	1	1	1	1	2	<1
PCB 118	3	ND	4	3	8	2
PCB 123	<1	<1	<1	<1	<1	<1
PCB 126	14	6	10	24	35	ND
PCB 156	1	5	1	2	3	1
PCB 157	<1	ND	<1	<1	1	<1
PCB 169	ND	ND	ND	<1	ND	ND
Other PCBs	<1	<1	<1	<1	<1	<1
Total Aroclors**	12	28	15	19	25	ND
Total Pesticides	**4**	**1**	**4**	**4**	**9**	**2**
Aldrin	ND	ND	ND	ND	ND	ND
Chlordane total	1	<1	1	1	2	ND
DDD	<1	<1	<1	<1	<1	ND
DDE	2	<1	2	2	3	2
DDT	1	<1	<1	<1	2	ND
Heptachlor Epoxide	ND	ND	ND	ND	ND	ND
Hexachlorobenzene	1	ND	1	1	2	ND
Total Dioxins/Furans	**14**	**11**	**9**	**14**	**9**	**36**
2,3,4,6,7,8-HxCDF	<1	ND	ND	<1	<1	1
2,3,4,7,8-PeCDF	4	2	1	6	1	4
2,3,7,8-TCDD	1	1	1	1	1	5
2,3,7,8-TCDF	4	4	5	2	3	5
OCDD	<1	<1	<1	<1	<1	<1
OCDF	<1	<1	<1	<1	ND	<1
1,2,3,7,8-PeCDD	4	3	2	4	2	16
1,2,3,4,7,8-HxCDD	<1	ND	ND	<1	<1	1
Other dioxins	1	1	<1	1	1	5

* Number in parenthesis is number of samples in basin data ** Based on adjusted Aroclor concentration (see Section 5.3.2)
ND = not detected

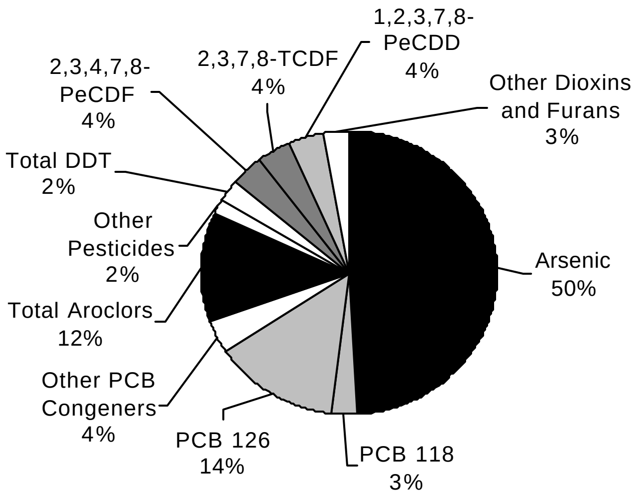


Figure 6-28. Percent contribution of basin-wide average chemical concentrations to cancer risk from consumption of spring chinook fillet with skin. Number of samples = 8.

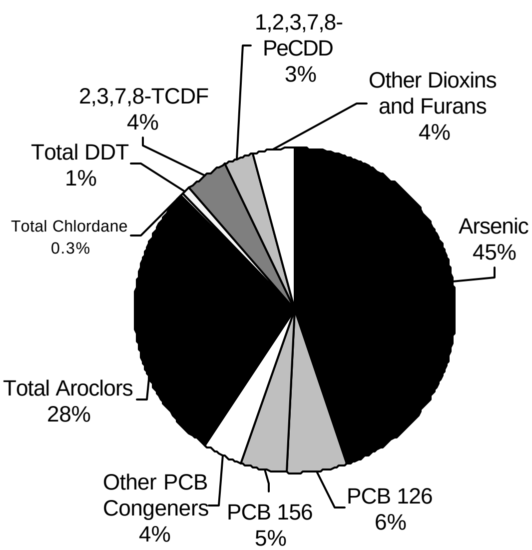


Figure 6-29. Percent contribution of basin-wide average chemical concentrations to cancer risk from consumption of coho salmon fillet with skin. Number of samples =3.

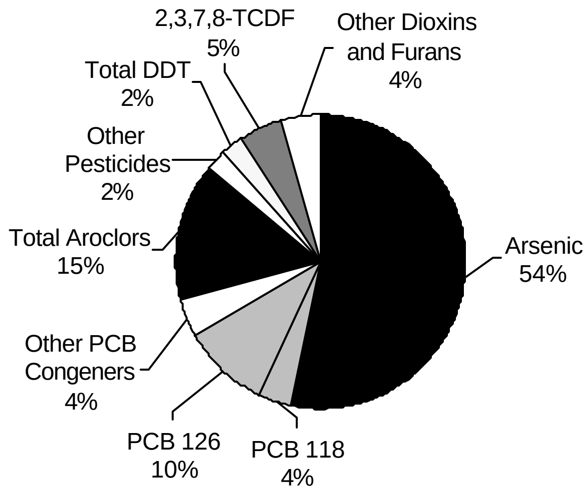


Figure 6-30. Percent contribution of basin-wide average chemical concentrations to cancer risk from consumption of fall chinook salmon fillet with skin. Number of samples = 15.

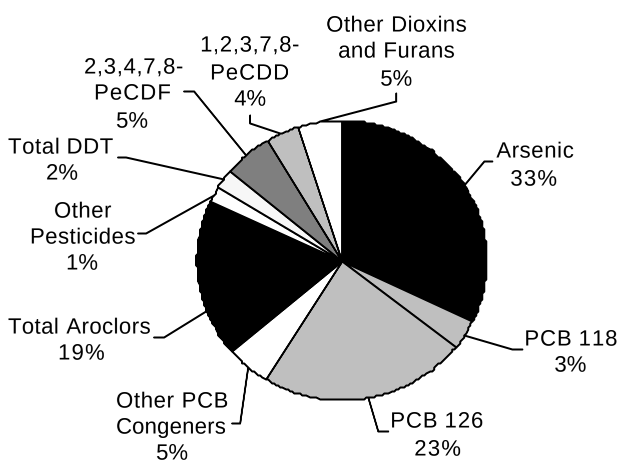


Figure 6-31. Percent contribution of basin-wide average chemical concentrations to cancer risk from consumption of steelhead fillet with skin. Number of samples = 21.

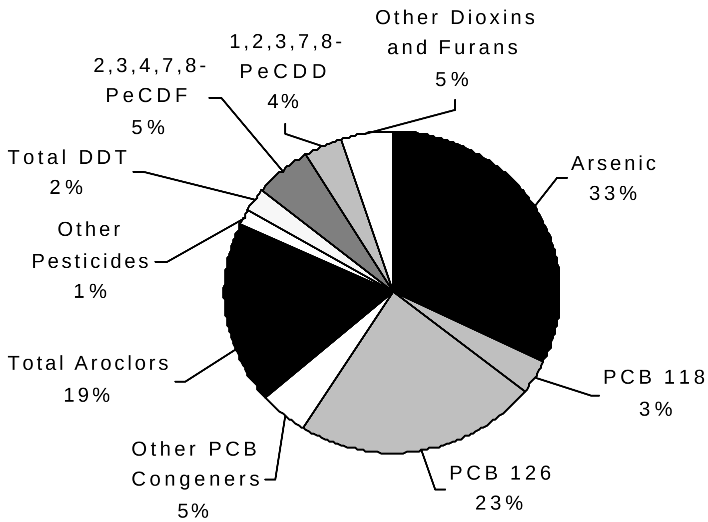


Figure 6-32. Percent contribution of basin-wide average chemical concentrations to cancer risk from consumption of Pacific lamprey fillet with skin. Number of samples =3.

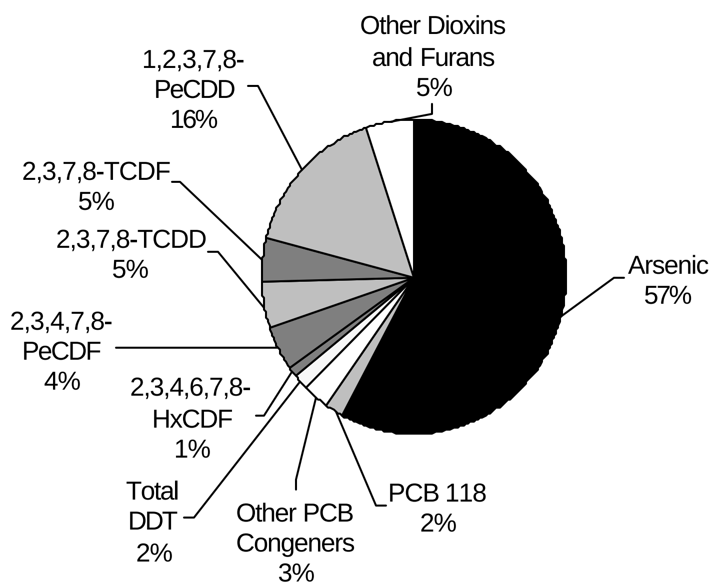


Figure 6-33. Percent contribution of basin-wide average chemical concentrations to cancer risk from consumption of whole body eulachon. Number of samples = 3.

6.2.2.3 Comparisons of Cancer Risks Between Anadromous Fish and Resident Fish Species

Table 6-18 shows a summary of the estimated total upper bound cancer risks for the basin and across study sites for all species at the high fish consumption rate for CRITFC's member tribal adults, 70 years exposure. It should be noted that the cancer risk estimates in Table 6-18 were calculated using high fish ingestion rates for CRITFC's member tribal adults, 70 years of exposure, while the results previously discussed for resident fish species in Table 6-14 and for anadromous fish species in Table 6-16 were calculated using average fish ingestion rates for CRITFC's member tribal adults, 70 years exposure. Conclusions from the comparisons in Table 6-18 are limited by the fact that different species were caught at different study sites and that sample numbers and types for each species varied.

Table 6-18 and the study site specific data in the tables in Appendices O and P show that for CRITFC's member tribal adults consuming fish at the high ingestion rate for 70 years:

- The basin-wide risks for *rainbow trout* and five of the anadromous fish (*coho, spring, and fall chinook salmon, steelhead, and eulachon*) were all estimated to be 1 X 10^{-3}. The range in the study site risks for the four species that had multiple study sites sampled was generally small: less than 2 fold for rainbow trout, fall chinook, and spring chinook. Steelhead had a slightly larger range (7 X 10^{-4} to 2 X 10^{-3}) due primarily to an estimated cancer risk of 7 X 10^{-4} at the Columbia River (study site 8); the estimated cancer risks for the other 5 study sites were at 1 or 2 X 10^{-3}.

- The basin-wide risk for *walleye* was 9 X 10^{-4}. The cancer risk for this one sample was within the range of study site risks for the species discussed in the previous bullet (rainbow trout, eulachon, the three salmon, and steelhead).

- The estimated basin-wide risks for high ingestion by adults in CRITFC's member tribes were greater than 1 X 10^{-3} among the remaining five species, with mountain whitefish and white sturgeon having the highest estimated basin-wide risks: *largescale sucker* (2 X 10^{-3}); *bridgelip sucker* (3 X 10^{-3}); *lamprey* (4 X 10^{-3}); *sturgeon* (6 X 10^{-3}), and; *whitefish* (8 X 10^{-3}). Three of these species had more than one study site used in the calculation of the basin-wide cancer risks, largescale sucker, sturgeon and whitefish. The range in cancer risks among the study sites sampled for sturgeon was about three-fold; for largescale sucker, about five-fold, and; for whitefish, about twenty-eight fold. The large difference in risk among study sites for whitefish was due to the low estimate of cancer risk of 7 X 10^{-4} for samples from the Umatilla (study site 101) and the high estimate of cancer risk of 2 X 10^{-2} at the Hanford Reach of the Columbia River (study site 9U). For sturgeon, no study site risk was less than 4 X 10^{-3}; the study site with the highest estimated cancer risk was the Columbia River at study site 9U.

Table 6-18. Summary of estimated total cancer risks by study site and basin-wide, all species. CRITFC's tribal member adult, high fish consumption, 70 years exposure

Species	N	Sample type	Range in study site cancer risks	Basin cancer risk
Resident species				
bridgelip sucker	*3*	WB	$3 X 10^{-3}$	$3 X 10^{-3*}$
largescale sucker	*19*	FS	$8 X 10^{-4}$ to $4 X 10^{-3}$	$2 X 10^{-3}$
mountain whitefish	*12*	FS	$7 X 10^{-4}$ to $2 X 10^{-2}$	$8 X 10^{-3}$
white sturgeon	*16*	FW	$4 X 10^{-3}$ to $1 X 10^{-2}$	$6 X 10^{-3}$
walleye	*3*	FS	$9 X 10^{-4}$	$9 X 10^{-4*}$
rainbow trout	*7*	FS	$1 X 10^{-3}$, $1 X 10^{-3}$	$1 X 10^{-3}$
Anadromous species				
coho salmon	*3*	FS	$1 X 10^{-3}$	$1 X 10^{-3*}$
fall chinook salmon	*15*	FS	$9 X 10^{-4}$ to $1 X 10^{-3}$	$1 X 10^{-3}$
spring chinook salmon	*24*	FS	1 to $2 X 10^{-3}$	$1 X 10^{-3}$
steelhead	*21*	FS	$7 X 10^{-4}$ to $2 X 10^{-3}$	$1 X 10^{-3}$
eulachon	*3*	WB	$1 X 10^{-3}$	$1 X 10^{-3*}$
Pacific lamprey	*3*	FS	$4 X 10^{-3}$	$4 X 10^{-3*}$

WB = whole body; FS = fillet with skin; FW = fillet without skin; N = number of samples

* Basin-wide cancer risks based on one study site

Figure 6-34 is a summary of the cancer risks estimated to result from consumption of the resident fish and anadromous fish at all four ingestion rates for adults: general public adult, average and high fish consumption; CRITFC's member tribal adult, average and high fish consumption, assuming 70 years exposure. (Note that the Y axis is on a logarithmic scale). Basin-wide fillet with skin data were used for this figure, except for those species that had only whole body samples (bridgelip sucker and eulachon) or fillet without skin samples (sturgeon). The basin-wide cancer risks vary by species, with mountain whitefish having the highest estimated cancer risks and white sturgeon having the second highest among the species sampled. Lamprey, bridgelip sucker and largescale sucker were the next highest followed by the remaining seven species - the three salmon, steelhead, eulachon, rainbow trout, and walleye.

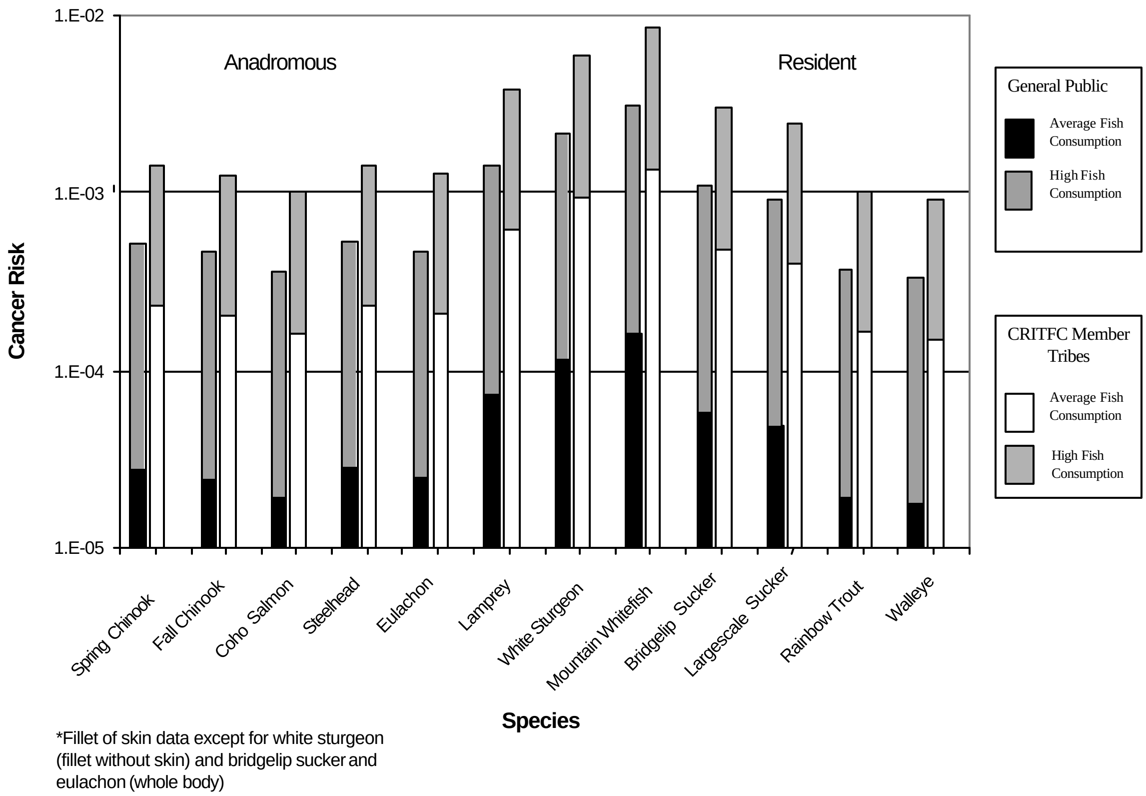


Figure 6-34. Adult estimated total cancer risks across all fish species sampled. Columbia River Basin-wide average data (70 years exposure).

For a more detailed comparison of cancer risks for anadromous fish and resident fish species for each study site, see Appendix N. In this appendix, estimated cancer risks are shown for all species caught at a sampling site using a range of fish ingestion rates.

The percent contribution of the chemicals and chemical classes to total cancer risk were shown in Tables 6-15 (resident fish species) and 6-17 (anadromous fish species) and in Figures 6-21 to 6-26 (resident fish species) and Figures 6-28 thru 6-33 (anadromous fish species). Fillet with skin data were used for these tables and figures except for sturgeon, for which fillet without skin data were used, and eulachon and bridgelip sucker, for which whole body data were used. A comparison of these tables and figures show that:

- Arsenic - For anadromous fish species, arsenic was a major contributor to cancer risk for all of the salmon and steelhead (33 to 54% for steelhead, fall and spring chinook, and coho salmon), and eulachon (58%), but contributes only 7% to the total cancer risk for lamprey. For resident fish, such a large contribution from arsenic was seen only for walleye (33%) and less so for bridgelip sucker (8%). As discussed in Section 4, it was assumed that 10% of the total arsenic measured in fish was inorganic. The impact of this assumption on the characterization of risk is discussed more in Section 6.2.6.

- PCBs - dioxin-like PCB congeners and Aroclors contribute from 32% to 82% of the total cancer risk for the resident fish; and from 32% to 77% for five of the anadromous fish, the exception being eulachon. For eulachon, dioxin-like PCB congeners/Aroclors contribute only 4% to the total cancer risk. For those 11 fish where dioxin-like PCB congeners/Aroclors were major contributors to risk, Aroclors 1254/1260 and, in general, dioxin-like PCBs 118, 126, and 156, contribute the most to the total dioxin-like PCB congener/Aroclor risk.

- Semi-volatiles - Semi-volatiles, including, PAHs, contribute little to the total risk. The exception was largescale sucker, where the contribution to the basin-wide average was 17% for dibenz(a,h,)anthracene and 8% for benzo(a)pyrene. This was misleading, however, because these two contaminants were found only at one of the six study sites where largescale sucker fillet were sampled, the Snake River at study site 13.

- Pesticides - For resident fish species, pesticides contribute from about 5% (for rainbow trout) to 32% (for bridgelip sucker) of the total cancer risk. For anadromous fish species, the percent contribution from pesticides was lower, from 1% (for coho salmon) to 9% (for lamprey). DDE was by far the major component of the pesticide cancer risk for resident fish species.

- Chlorinated Dioxins/Furans - Chlorinated dioxins/furans contribute from 5% (for largescale sucker) to 36% (for sturgeon) of the total cancer risk for resident fish species. Dioxins/furans contribute 36% to the eulachon cancer risk, but only 9% for lamprey and chinook salmon, 11% for coho, and 14% for steelhead and spring chinook. For resident fish species, 2,3,7,8-TCDF, 1,2,3,7,8-PCDD, and 2,3,7,8-TCDD were the major contributors to the dioxin/furan cancer risk. For the anadromous fish species, 2,3,7,8-TCDF, 1,2,3,7,8-PCDD, and 2,3,4,7,8-PCDF were the major contributors.

6.2.3 Summary of Non-Cancer Hazards and Cancer Risks for All Species

Tables 6-19 through 6-22 are a summary of the range in endpoint specific hazard indices and cancer risks across study sites for each species at the four fish ingestion rates used for adults. Hazard indices are shown only for those endpoints that most frequently exceeded a hazard index of 1. These endpoints are for reproduction/development and the central nervous system, immunotoxicity, and liver resulting primarily from exposures greater than the reference dose for methyl mercury, Aroclors, and DDT, DDE and DDD. Cancer risks are those estimated assuming a 70 year exposure duration.

- Hazard indices and cancer risks were lowest for the general public adult at the average ingestion rate and highest for CRITFC's member tribal adults at the high ingestion rate. For the general public with an average fish ingestion (7.5 g/day or about a meal per month), hazard indices were less than 1 and cancer risks are less than 1 X 10^{-4} except for a few of the more highly contaminated samples of mountain whitefish and white sturgeon (Table 6-19).

- For CRITFC's member tribal adults at the highest fish ingestion rates (389 g/day or about 48 meals per month), hazard indices were greater than 1 for several species at some study sites. Hazard indices (less than or equal to 8 at most study sites) and cancer risks (ranging from 7 X 10^{-4} to 2 X 10^{-3}) were lowest for salmon, steelhead, eulachon and rainbow trout and highest (hazard indices greater than 100 and cancer risks up to 2 X 10^{-2} at some study sites) for mountain whitefish and white sturgeon (Table 6-22).

- As discussed previously in Section 6.2.1, for the general public, the hazard indices for children at the average fish ingestion rate were about 0.9 those for adults at the average ingestion rate; the hazard indices for children at the high ingestion rate were about 1.3 times those for adults at the high ingestion rate. For CRITFC's member tribes, the hazard indices for children at the average and high ingestion rates were both about 1.9 times those for CRITFC's member tribal adults at the average and high ingestion rates, respectively.

Table 6-19. Summary of Hazard Indices and Cancer Risks Across Study sites. General Public Adult, average fish consumption (7.5 grams/day or 1 meal per month).

Species*	N*	Non-cancer endpoints which most frequently exceed a hazard index of one for all species			Cancer Risks (70 years exposure)
		Reproductive/ Developmental And Central Nervous System	Immunotoxicty	Liver	
Resident species					
bridgelip sucker	*3*	<1	<1	<1	6 X 10^{-5}
largescale sucker	*19*	<1	<1	<1	2 to 7 X 10^{-5}
mountain whitefish	*12*	<1	<1 to 3	<1	1 X 10^{-5} to 5 X 10^{-4}
white sturgeon	*16*	<1	<1 to 2	<1	7 X 10^{-5} to 3 X 10^{-4}
walleye	*3*	<1	<1	<1	2 X 10^{-5}
rainbow trout	*7*	<1	<1	<1	2 X 10^{-5}, 2 X 10^{-5}
Anadromous species					
coho salmon	*3*	<1	<1	<1	2 X 10^{-5}
fall chinook	*15*	<1	<1	<1	2 - 3 X 10^{-5}
spring chinook	*24*	<1	<1	<1	2 - 3 X 10^{-5}
steelhead	*21*	<1	<1	<1	1 to 3 X 10^{-5}
eulachon	*3*	<1	<1	<1	2 X 10^{-5}
Pacific lamprey	*3*	<1	<1	<1	7 X 10^{-5}

* N = number of samples. All samples are fillet with skin except sturgeon (fillet without skin) and bridgelip sucker and eulachon (whole body)

Table 6-20. Summary of Hazard Indices and Cancer Risks Across Study sites. General Public Adult, high fish consumption (142.4 g/day or 19 meals per month).

Species*	N*	Non-cancer endpoints which most frequently exceed a hazard index of one for all species: Reproductive/ Developmental and Central Nervous system	Immunotoxicty	Liver	Cancer Risks (70 years exposure)
Resident species					
bridgelip sucker	*3*	<1	6	2	1 X 10^{-3}
largescale sucker	*19*	2 to 7	1 to 8	<1 to 3	3 X 10^{-4} to 1 X 10^{-3}
mountain whitefish	*12*	<1 to 3	1 to 50	<1 to 4	2 X 10^{-4} to 9 X 10^{-3}
white sturgeon	*16*	1 to 7	6 to 40	2 to 8	1 to 5 X 10^{-3}
walleye	*3*	4	1	1	3 X 10^{-4}
rainbow trout	*7*	1 to 2	1 to 2	<1	4 X 10^{-4}, 4 X 10^{-4}
Anadromous species					
coho salmon	*3*	2	3	<1	4 X 10^{-4}
fall chinook	*15*	1 to 2	<1 to 3	<1	3 to 5 X 10^{-4}
spring chinook	*24*	<1 to 6	1 to 2	<1	4 to 6 X 10^{-4}
steelhead	*21*	1 to 3	1 to 2	<1	3 to 6 X 10^{-4}
eulachon	*3*	<1	<1	<1	5 X 10-^{4}
Pacific lamprey	*3*	<1	9	<1	1 X 10^{-3}

* N = number of samples; All samples are fillet with skin except sturgeon (fillet without skin) and bridgelip sucker and eulachon (whole body)

Table 6-21. Summary of Hazard Indices and Cancer Risks Across Study sites. CRITFC's Member Adult, average fish consumption (63.2 grams/day or 8 meals per month).

Species	N	Non-cancer endpoints which most frequently exceed a hazard index of one for all species: Reproductive/ Developmental and Central Nervous System	Immunotoxicty	Liver	Cancer Risks (70 years exposure)
Resident species					
bridgelip sucker	*3*	<1	3	1	5 X 10^{-4}
largescale sucker	*19*	<1 to 3	<1 to 3	<1 to 1	1 to 6 X 10^{-4}
mountain whitefish	*12*	<1 to 1	<1 to 22	<1 to 2	1 X 10^{-4} to 4 X 10^{-3}
white sturgeon	*16*	<1 to 3	3 to 18	<1 to 3	6 X 10^{-4} to 2 X 10^{-3}
walleye	*3*	2	<1	<1	2 X 10^{-4}
rainbow trout	*7*	<1	<1	<1	2 X 10^{-4}, 2 X 10^{-4}
Anadromous species					
coho salmon	*3*	1	1	<1	2 X 10^{-4}
fall chinook	*15*	<1 to1	1	<1	1 to 2 X 10^{-4}
spring chinook	*24*	<1 to 3	<1	<1	2 to 3 X 10^{-4}
steelhead	*21*	<1 to 1	<1 to 1	<1	1 to 3 X 10^{-4}
eulachon	*3*	<1	<1	<1	2 X 10^{-4}
Pacific lamprey	*3*	<1	4	<1	6 X 10^{-4}

N = number of samples. All samples are fillet with skin except sturgeon (fillet without skin).
Bridgelip sucker and eulachon are whole body fish tissue samples.

Table 6-22. Summary of Hazard Indices and Cancer Risks Across Study sites. CRITFC's Member Adult, high fish consumption (389 grams/day or 48 meal per month)

Species*	N*	Non-cancer endpoints which most frequently exceed a hazard index of one for all species			Cancer Risks (70 years exposure)
		Reproductive/ Developmental and Central Nervous System	Immunotoxicty	Liver	
Resident species					
bridgelip sucker	*3*	2	17	6	3 X 10^{-3}
largescale sucker	*19*	5 to 20	<1 to 21	<1 to 7	8 X 10^{-4} to 4 X 10^{-3}
mountain whitefish	*12*	<1 to 7	4 to 140	<1 to 11	7 X 10^{-4} to 2 X 10^{-2}
white sturgeon	*16*	3 to 20	16 to 108	6 to 21	4 X 10^{-3} to 1 X 10^{-2}
walleye	*3*	10	4	4	9 X 10^{-4}
rainbow trout	*7*	4 to 5	3 to 4	<1	1 X 10^{-3}, 1 X 10^{-3}
Anadromous species					
coho salmon	*3*	7	7	<1	1 X 10^{-3}
fall chinook	*15*	3 to 6	<1 to 8	<1	9 X 10^{-4} to 1 X 10^{-3}
spring chinook	*24*	<1 to 17	3 to 6	<1	1 to 2 X 10^{-3}
steelhead	*21*	4 to 8	3 to 6	<1	7 X 10^{-4} to 2 X 10^{-3}
eulachon	*3*	<1	<1	<1	1 X 10^{-3}
Pacific lamprey	*3*	<1	24	2	4 X 10^{-3}

N = number of samples. All samples are fillet with skin except sturgeon (fillet without skin).
Bridgelip sucker and eulachon are whole body fish tissue samples.

6.2.4 Impacts of Sample Type on Risk Characterization

For this study, both whole fish and fillet with skin samples were analyzed for all species except sturgeon, bridgelip sucker, and eulachon. Sturgeon were analyzed as whole fish and fillet without skin (since it is unlikely that sturgeon skin is eaten). For bridgelip sucker and eulachon only whole body samples were collected.

The risk characterization results for all species and sample types are included in the appendices. However, some of the risk characterization results previously discussed in Sections 6.2.1 and 6.2.2 focused on fillet with skin samples (except for those species for which fillet with skin were not collected). To determine the impact that tissue type might have on the risk characterization, the ratio of the estimated hazard indices and cancer risks for whole body to fillet samples were calculated (Table 6-23). These results were calculated for those species that had both fillet and whole body samples analyzed at a given site. For non-cancer effects, whole body to fillet ratios were calculated for the total hazard index as well as for the endpoints of immunotoxicity and reproduction. Table 6-23 also shows the number of whole body to fillet ratios that were greater than 1 compared to the total number of whole body to fillet ratios calculated for that species.

As can be seen from Table 6-23, there does not appear to be a consistent pattern in whole body to fillet ratios for the total hazard indices, the immunotoxicity hazard indices, or cancer risks at a given site for a species. The whole body to fillet ratios ranged from a low of 0.4 to a high of 6.6. Most of the ratios were less than 3. These results are consistent with the results in Section 2 of this report. In Section 2, it was shown that while whole body fish tissue samples tend to be somewhat higher in lipids and lipid soluble contaminants than fillet with skin samples for some species, these differences between whole body and fillet fish samples were not consistent across species. For reproductive effects, the ratios of the hazard indices for reproductive effects in whole body to fillet samples appear to be less than 1 more frequently than those for the other hazard indices or cancer risks. This may be because the hazard index for reproductive effects is based largely upon the contaminant mercury which is not lipophilic and binds strongly to protein (e.g., muscle tissue). However, any conclusions on the results of whole body to fillet samples are limited by the small sample sizes (usually 3) at each site and by the fact that whole body samples were always from a composite of fish different than those used for the whole body analysis (i.e., fillet and whole body samples are not from the same fish).

Table 6-23. Comparison of site specific non-cancer hazard indices (for CRITFC's member tribal children) and cancer risks (for CRITFC's member tribal adults) from consuming whole body versus fillet for different fish species.

	Hazard Indices (1)							
	Immunotoxicity		Reproductive Effects		Total Hazard Index		Cancer Risk (2)	
Species	Range in ratios of hazard indices for whole body/fillet across sites	F	Range in ratios of hazard indices for whole body/fillet across sites	F	Range of ratios of total hazard indices for whole body/fillet across sites	F	Range of ratios of cancer risks for whole body/fillet	F
coho	1.1	(1/1)	0.8	(0/1)	1.1	(1/1)	1	(0/1)
fall chinook	0.9 - 6.6	(3/5)	0.7-1.1	(1/5)	1.0 - 1.6	(3/5)	1 - 2	(2/5)
spring chinook	0.9 - 1.6	(4/8)	0.3 - 1.1	(1/3)	0.6 - 1.6	(4/8)	1 - 2	(3/8)
steelhead	1.1 - 1.4	(6/6)	0.6 - 1.6	(1/6)	0.9 - 1.5	(4/6)	0.5 - 2.0	(2/6)
eulachon	na	na	na	na	na	na	na	na
Pacific lamprey	1	(0/1)	na	na	1.2	(1/1)	1	(0/1)
bridgelip sucker	na	na	na	na	na	na	na	na
largescale sucker	0.6 - 3.3	(3/5)	0.2 - 1.3	(1/6)	0.5 - 2.2	(3/6)	0.7 - 2.5	(3/6)
mountain whitefish	0.4 - 2.1	(2/4)	0.7 - 0.9	(0/3)	0.8 - 1.6	(2/4)	0.5 - 1.4	(1/4)
white sturgeon	0.4- 2.9	(1/3)	0.3 - 3.3	(2/3)	0.4 - 2.7	(1/3)	0.8 - 2.3	(1/3)
walleye	1.8	(1/1)	1	(0/1)	1	(0/1)	1	(1/1)
rainbow trout	1.2 - 1.2	(2/2)	0.7- 1.7	(½)	1.1 - 1.5	(2/2)	1.0 - 1.0	(0/2)

F=Frequency of number of whole body to fillet ratios greater than 1 divided by the total number of whole body to fillet ratios for that species.
na = Not applicable; ratios could not be calculated because chemicals (Aroclors, mercury) were less than detection limits or because fillet data were not available (I.e., for bridgelip sucker and eulachon)
(1) Hazard indices used are those calculated for CRITFC's tribal member children, high fish consumption rate
(2) Cancer risk are those calculated for CRITFC's tribal member adults, 70 years exposure, high fish consumption

6.2.5 Risk Characterization Using a Multiple-species Diet

As discussed in Section 4.10, a hypothetical diet consisting of multiple fish species was developed based on information obtained during the 1991-1992 survey of fish consumption by members of the Nez Perce, Umatilla, Yakama, and Warm Springs Tribes (CRITFC, 1994). The percentage of the hypothetical diet assumed for each fish species and the resulting species specific ingestion rates (assuming a total fish ingestion rate of 63.2 g/day, the average for CRITFC’s tribal members adults) were shown previously in Table 4-4.

Table 6-24 shows the resulting cancer risks and total non-cancer hazard indices calculated using this hypothetical diet and the average fish consumption rate (63.2 grams/day) for CRITFC's member tribal adult fish consumers. Cancer risk estimates for individual species were highest for lamprey fillets (1.0×10^{-4}) and lowest for walleye fillets (4.2×10^{-6}). The total excess cancer risk for consuming the fish used in this example was 4.0×10^{-4}. Total hazard indices for individual species were highest for lamprey and mountain whitefish fillets (0.7) and lowest for eulachon and largescale sucker fillets (0.1). The total hazard index for consuming the fish used in this example was 3.2.

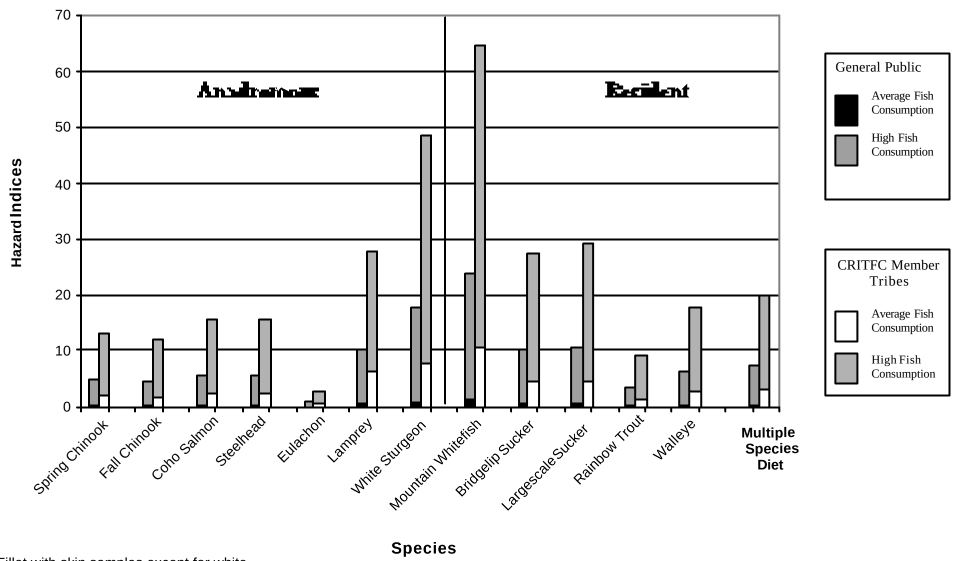
Table 6-24. Estimate cancer risks and non-cancer health effects for a hypothetical multiple-species diet based upon CRITFC's member average adult fish consumption (CRITFC, 1994)

Species	Percentage of Hypothetical	Consumption Rate (g/day)	Cancer Risk[a]	Non-cancer Effects[a]
Salmon[b,c,d]	27.7	17.5	5.8×10^{-5}	0.6
Rainbow Trout[d]	21.0	13.3	3.5×10^{-5}	0.3
Mountain Whitefish[d]	6.8	4.3	9.3×10^{-5}	0.7
Eulachon[e]	15.6	9.9	3.3×10^{-5}	0.1
Pacific lamprey[d]	16.3	10.3	1.0×10^{-4}	0.7
Walleye[d]	2.8	1.8	4.2×10^{-6}	0.1
White Sturgeon[f]	7.4	4.7	7.1×10^{-5}	0.6
Largescale Sucker[d]	2.3	1.5	9.3×10^{-6}	0.1
Totals	100.0	63.2	4.0×10^{-4}	3.2

[a]Risk estimates assume fish consumption by a 70 kg CRITFC's tribal member adult at the specified rate 365 days per year for 70 years
[b]Cancer risk estimates for salmon are the average of estimates for spring chinook (6.4×10^{-5}), fall chinook (5.7×10^{-5}), coho (4.5×10^{-5}), and steelhead (6.4×10^{-5}).
[c]Noncancer hazard indices for salmon are the average of estimates for spring chinook (0.6), fall chinook (0.5), coho (0.7), and steelhead (0.7).
[d]Risk estimates are based on analysis of uncooked composite samples of fillets with skin.
[e]Risk estimates are based on analysis of uncooked composite samples of whole body fish.
[f]Risk estimates are based on analysis of uncooked composite samples of fillets without skin.

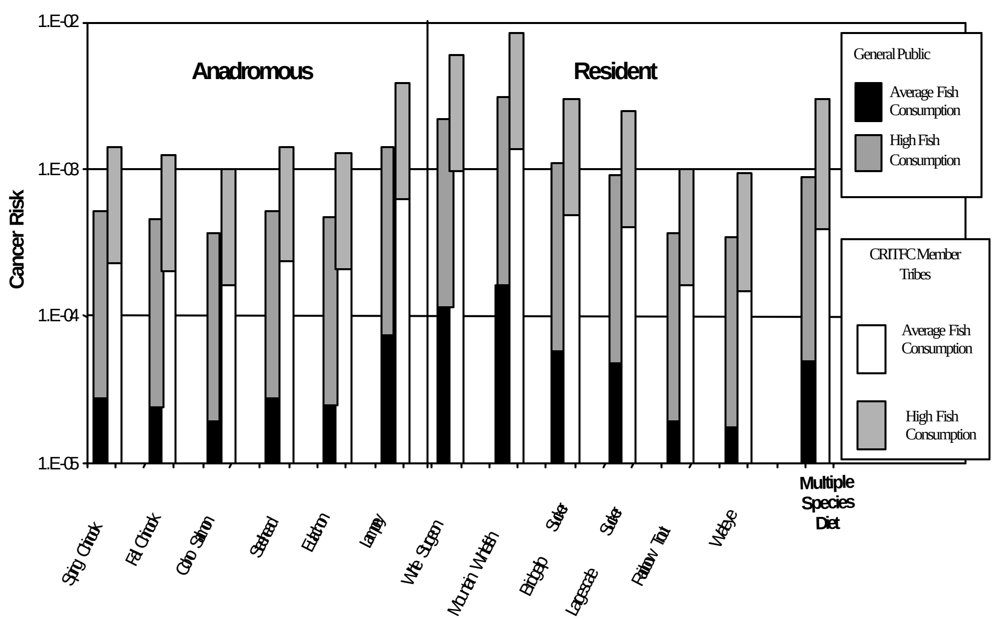
Figure 6-35 shows the total non-cancer hazard indices and Figure 6-36 shows the total cancer risks (70 years exposure) across all species with the results for the multiple-species diet shown for comparison. The results for both general public adult (average and high fish consumption) and CRITFC's member tribal adults (average and high fish consumption) using basin-wide data are included. For all four populations, the hypothetical diet of multiple species based on CRITFC's fish consumption survey was used. The non-cancer hazards and cancer risks for the multiple-species diet were lower than those for the most contaminated species (e.g., sturgeon and whitefish) and higher than those estimated for some of the least contaminated species (e.g., salmon, steelhead, rainbow trout, and eulachon).

These results demonstrate that the non-cancer hazards and cancer risks previously discussed in Sections 6.2.1 and 6.2.2 for individual species may not adequately reflect the cancer risks and non-cancer hazards for CRITFC's member tribes or other individuals from the general public whose diets are composed of a mixture of fish types from the Columbia River Basin.



*Fillet with skin samples except for white sturgeon (fillet without skin) and bridgelip sucker and eulachon (whole body)

Figure 6-35. Adult total hazard indices for all fish species, with multiple-species diet results. Basin-wide average data.



*Fillet with skin samples except for white sturgeon (fillet without skin) and bridgelip sucker and eulachon (whole body)

Figure 6-36. Adult cancer risks for all species, with multiple-species diet results. Columbia River Basin-wide average chemical concentration data. 70 years exposure.

6.2.6 Risk Characterization Using Different Assumptions for Percent of Inorganic Arsenic

As discussed in Section 5.3.3, total arsenic was measured in fish tissue samples in this study. Because a reference dose and cancer slope factor are available for only inorganic arsenic, an assumption about the percent of inorganic arsenic in fish had to be made to estimate the non-cancer hazards and cancer risks from consuming fish. The non-cancer hazards and cancer risks discussed in Section 6.2.1 and 6.2.2, respectively, assumed that for all fish species (resident fish and anadromous fish) caught in this study, 10% of the total arsenic was inorganic arsenic. The studies used to derive this value of 10% and the rationale for its selection were discussed in Section 5.3.3. The data in Section 5.3.3 also suggests that an alternative assumption for anadromous fish species could be considered - the assumption that 1% of the total arsenic was inorganic. Therefore, the non-cancer hazards and cancer risk were recalculated for anadromous fish species using basin-wide data assuming that 1% of the total arsenic was inorganic. The assumption of 1% inorganic arsenic for anadromous fish species in effect results in a contaminant level for arsenic that one tenth of that assuming that 10% was inorganic arsenic.

Table 6-25 shows the impact of the two different assumption (10% and 1% inorganic) on the estimated total hazard indices for anadromous fish species using basin-wide data. These results are shown for general public and CRITFC's member tribal adults at both the average and high fish consumption rates. As can be seen from this table and from Figure 6-37, assuming that 1% of total arsenic was inorganic rather than 10%, the total hazard indices were reduced by 2% for lamprey, 6% for coho and steelhead, and 11% for spring and fall chinook. However, for eulachon, the assumption of 1% inorganic arsenic reduces the total basin-wide hazard index for this fish species by 56%. The effect of this assumption on risks due to ingestion of eulachon was consistent with the data in Table 6-7 which showed the percent contribution of different contaminants on the basin-wide total hazard indices for anadromous fish species. Arsenic contributed from about 2% to 13% to the total hazard index for salmon, steelhead, and lamprey but about 60% to that for eulachon. Thus, assuming that inorganic arsenic represents 1% rather than 10% of total arsenic had the largest impact on the total non-cancer hazards for eulachon (a 56% reduction in the total hazard index) and less of an impact on the other anadromous fish species.

Table 6-25. Total hazard indices (HIs) for adults assuming that total arsenic is 1% versus 10% inorganic arsenic. Exposure concentrations used to estimate risks are Columbia River Basin-wide averages of fish tissue samples

					Average Fish Consumer		High Fish Consumer	
					Total HI			
Species	**N**	**Tissue Type**	**Percent Inorganic Arsenic as Total Arsenic**	**Percent Decrease In Total HI Assuming 1% Inorganic Arsenic**	**general public**	**CRITFC member tribe**	**general public**	**CRITFC member tribe**
coho salmon	*3*	FS	10		0.3	2.5	5.7	15.7
			1	6	0.3	2.4	5.4	14.8
spring chinook	*24*	FS	10		0.3	2.1	4.8	13.0
			1	11	0.2	1.9	4.2	11.6
fall chinook	*15*	FS	10		0.2	2.0	4.4	12.0
			1	11	0.2	1.7	3.9	10.7
steelhead	*21*	FS	10		0.3	2.6	5.7	15.7
			1	6	0.3	2.4	5.4	14.8
eulachon	*3*	WB	10		0.1	0.4	1.0	2.7
			1	56	0.0	0.2	0.4	1.2
Pacific lamprey	*3*	FS	10		0.5	4.5	10.1	27.7
			1	2	0.5	4.4	9.9	27.1

N= Number of samples; FS = fillet with skin; WB = whole body

Total HI is determined by summing all hazard quotients regardless of health endpoint.

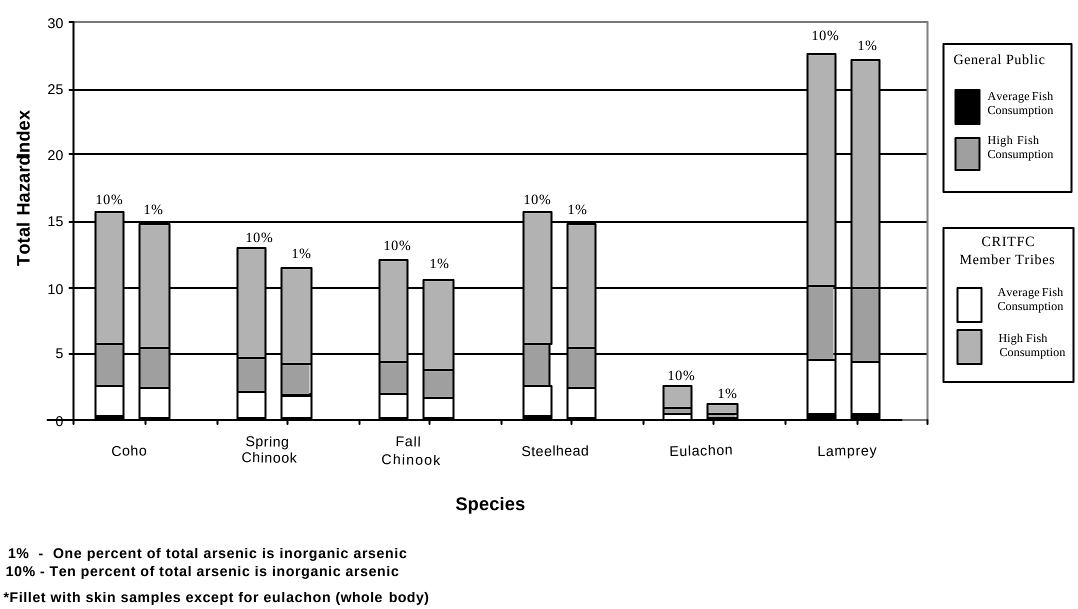


Figure 6-37. Impact of percent inorganic arsenic on total hazard index. Basin-wide data for anadromous fish species*.

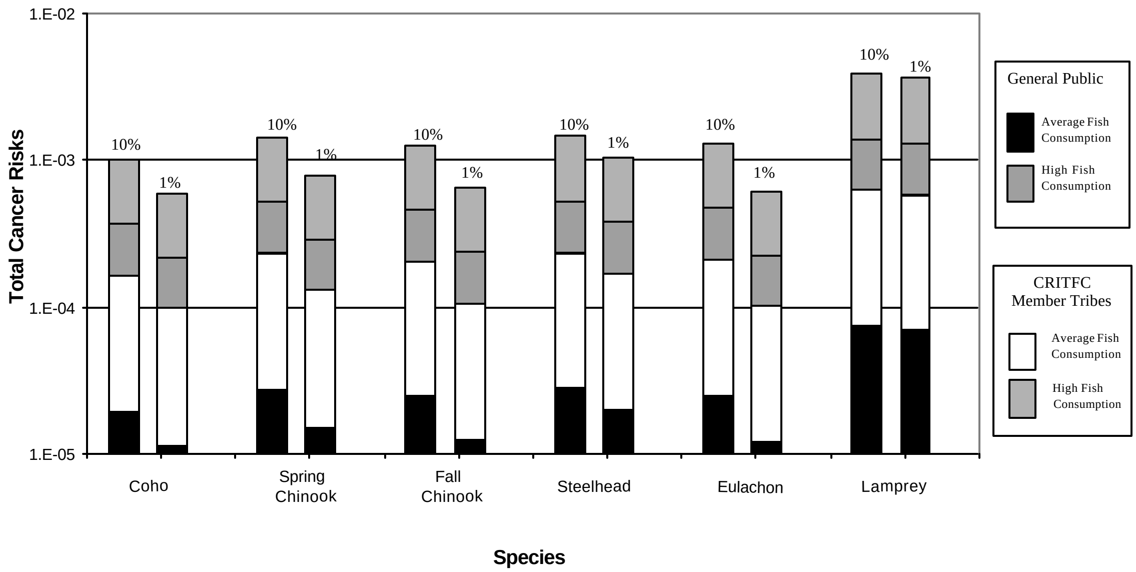
Tables 6-26 and Figure 6-38 show the impact of the two different assumptions (10% and 1% inorganic arsenic as total arsenic) on the estimated total cancer risks for anadromous fish species using basin-wide data. These results are shown for general public and CRITFC's member tribal adults at both the average and high fish consumption rates and 70 years of exposure. Assuming that 1% of total arsenic was inorganic versus 10%, the cancer risks were reduced about 6% for lamprey, 29% for steelhead, and between 40% to 52% for coho, spring chinook, fall chinook and eulachon. These results are consistent with those previously discussed for Table 6-17 (percent contribution of different contaminants on the basin-wide total cancer risk for anadromous fish species) which showed that arsenic was a major contributor to the total cancer risks for all anadromous fish species except Pacific lamprey.

Table 6-26. Estimated total cancer risks for adults assuming that total arsenic was 1% versus 10% inorganic arsenic 70 years exposure. Exposure concentrations used to estimate risks are Columbia River Basin-wide averages of fish tissue samples.

					Average Fish Consumer		High Fish Consumer	
					Total Cancer Risk			
Species	N	Tissue Type	Percent Inorganic Arsenic as Total Arsenic	Percent Decrease In Total Cancer Risk Assuming 1% Inorganic Arsenic	general public	CRITFC member tribe	general public	CRITFC member tribe
coho salmon	*3*	FS	10		1.9E-05	1.6E-04	3.7E-04	1.0E-03
			1	40.4	1.1E-05	9.7E-05	2.2E-04	6.0E-04
spring chinook	*24*	FS	10		2.8E-05	2.3E-04	5.2E-04	1.4E-03
			1	44.6	1.5E-05	1.3E-04	2.9E-04	7.9E-04
fall chinook	*15*	FS	10		2.4E-05	2.0E-04	4.6E-04	1.3E-03
			1	48.4	1.2E-05	1.1E-04	2.4E-04	6.5E-04
steelhead	*21*	FS	10		2.8E-05	2.3E-04	5.3E-04	1.4E-03
			1	29.3	2.0E-05	1.7E-04	3.7E-04	1.0E-03
eulachon	*3*	WB	10		2.5E-05	2.1E-04	4.7E-04	1.3E-03
			1	52.0	1.2E-05	1.0E-04	2.3E-04	6.2E-04
Pacific lamprey	*3*	FS	10		7.4E-05	6.2E-04	1.4E-03	3.8E-03
			1	6.1	6.9E-05	5.8E-04	1.3E-03	3.6E-03

N = Number of samples; FS = fillet with skin; WB = whole body

This comparison of the results from using the two different assumptions (1% versus 10%) for inorganic arsenic in fish shows that the reduction on the total non-cancer hazards was less than 12% for all anadromous fish species, except eulachon which had about a 50% reduction. However, the impact was greater on the estimates of cancer risk. With the exception of lamprey for which cancer risks were reduced by only 6%, the reductions in cancer risks for steelhead was about 29% and for the other anadromous fish species ranged from about 40 to 50%.



1% - One percent of total arsenic is inorganic arsenic
10% - Ten percent of total arsenic is inorganic arsenic

***Fillet with skin samples except for eulachon (whole body)**

Figure 6-38. Impact of percent inorganic arsenic on cancer risks. Basin-wide data for anadromous fish species.